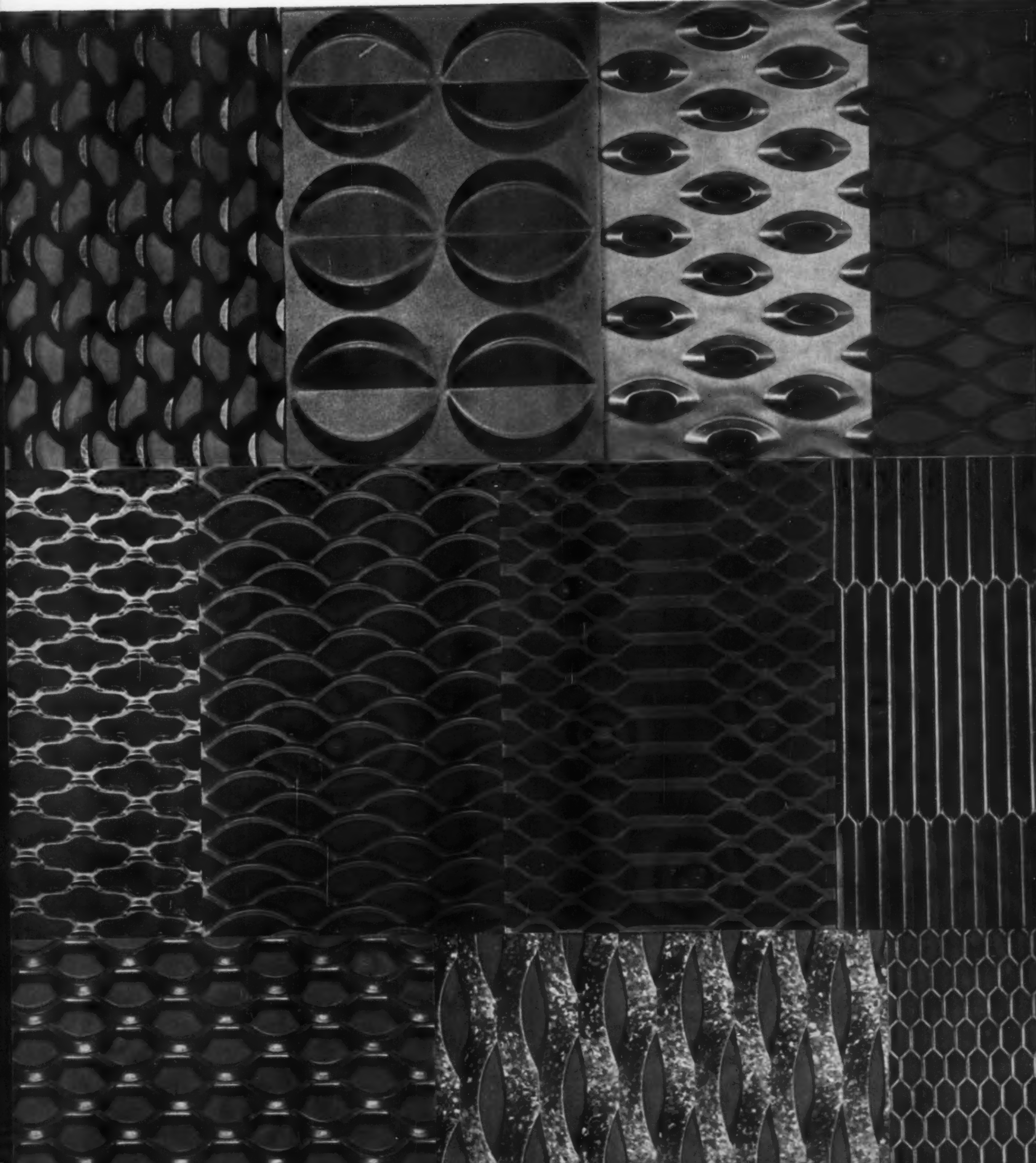
Metal Progress

MAY 1960



The 180-cycle Multiductor, a low-cost static frequency converter, permits the use of induction on heating and melting applications where costs were previously prohibitive.

THE NAME WITH THE FAMILIAR RING!

The Multiductor, one of several Power Sources . . . another major product line of AM for the heating or melting of metals by Induction.

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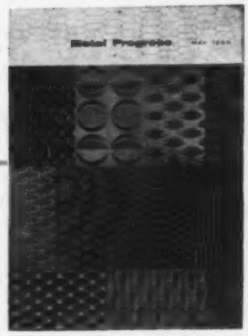
Circle 1715 on Page 48-A

Metal Progress

May 1960 . . . Volume 77, No. 5



Striking examples of aluminum fabrication and coloring were provided for this month's cover by the Aluminum Co. of America. An explanatory note on p. 91 lists the fabricators.

Table of Contents Continued on Page 3

**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

How service life of a furnace I-beam was increased 400%

Electro-Alloys' knowledge of thermal fatigue lead to a simple solution

As a result of cyclical heating and cooling, heat-treating equipment, trays, rolls, tubes and other furnace components, are particularly vulnerable to thermal fatigue. This failure mechanism is not easily spotted. Therefore, the natural course of user and supplier of heat-resistant castings is to try to strengthen the component through the addition of braces, gussets, tie rods and other restricting members or through making heavier metal sections.

Almost inevitably this procedure results in an even shorter service life. The reason: a greater number of design members and heavier metal sections accelerate thermal fatigue.

An interesting study in thermal fatigue and how it was minimized is shown in the Figures at the right.

I-beam was failing after 4-6 months

The beam, shown in Figure 1, supported tube stock heated for welded tubing. After 4-6 months service, the beam would crack and fail at Area "A".

Preliminary calculations proved that the beam was more than adequate in strength. Therefore, Electro-Alloys engineers concentrated their study on the thermal factors of the furnace operation. As shown in Figure 1, the burners were firing below the beam, and special precautions had been taken to insure that the burner flame did not impinge on the cast-alloy beam. But, as also shown, the flame traveling across the furnace strikes a slanted pier and deflects into the casting at Area A. The high concentration of heat at "A" causes the flange to expand more rapidly than the web. This condition created the failure shown in Figure 2 and in the photographic close-up, Figure 3.

To all intents, the failure had the implications of a weak beam . . . buckling, cracking and downward deformation. The approach to solving this problem could be to increase the metal sections or to add restricting members.

Simple baffle extends beam life 400%

Electro-Alloys solution of the problem was not the design of a new beam but the far simpler design of a loose baffle to fit the beam, see Figure 4. This baffle could take the thermal shock. It was small, flexible and could deform at will without detracting from the strength of the beam.

This simple baffle has lengthened beam life 400%.

Avoiding expensive thermal-fatigue pitfalls

Users and designers of heat-resistant castings are vulnerable, generally, to two pitfalls that lead to losses in service life and operating economy:

a. Too much faith in the calculation of applied stresses as the measure of the casting's ability to withstand service conditions. This is reflected by increasing the size or number of restricting members . . . braces, gussets and tie rods.

b. Assuming that an alloy operating well at 2000° F. will work just as well in a different application where maximum temperature is only 1700° F.

These pitfalls are a natural outgrowth of the lack of information on thermal fatigue, an important cause of heat-resistant casting failures.

Electro-Alloys is recognized as a leading authority on thermal fatigue and high-alloy casting design. Case histories, such as the one reported here, and the widely published test data emanating from the Research Laboratory at Mahwah, N. J., are evidence of this.

● *Most recent of these reports is "The Mechanism of Thermal Fatigue," by H. S. Avery. Copies of this study are available on request. Simply write to Electro-Alloys Division, 2015 Taylor Rd., Elyria, Ohio.*

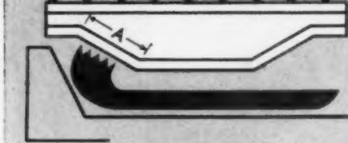


FIGURE 1

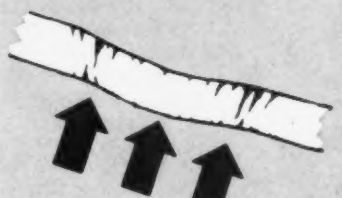


FIGURE 2

FIGURE 3

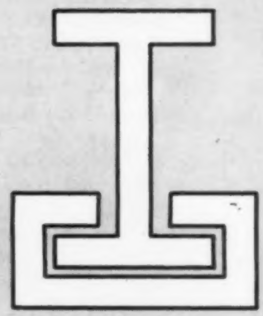


FIGURE 4

American Brake Shoe Company

ELECTRO-ALLOYS DIVISION • Elyria, Ohio

Metal Progress

Data Sheet

Engineering Articles

Correspondence

Metals Engineering Digest

Departments

Metal Progress is published monthly by the American Society for Metals, Publication office Mt. Morris, Ill. Editorial and general offices Metals Park, Novelty, Ohio. Second-class postage paid at Mt. Morris, Ill. Vol. 77, No. 5, May 1960.

By the drumful, shovelful, scoopful, handful, or spoonful . . . Sherritt nickel is about the most convenient alloying metal you can buy. No wrestling with unwieldy plates. No cutting or hacking. High-purity Sherritt nickel comes to you in handy briquettes and in three grades of powder for faster, easier alloying. These powders and briquettes go into solution more rapidly with less chilling. You can make alloying additions at the end of the heat. Special nickel grades and coated powders are also available.

FOOTE MINERAL COMPANY *is the exclusive sales agent for Sherritt nickel and cobalt in the United States and Canada. For complete illustrated brochure with prices and delivery information, contact the Foote Mineral Company, 424S Eighteen West Chelten Building, Philadelphia 44, Pa.*

SHERRITT GORDON MINES LIMITED

PRESS BREAKS

The striking photograph on p. 97 which introduces the special report on modern tool materials and metal fabrication was supplied by Peterson Products Corp., Schiller Park, Ill.

Cover Competition

In "Press Breaks" some months ago we commented on the fact that many *Metal Progress* covers during the last 15 years had been secured from annual competitions by students in advertising art at the Cleveland Institute of Art. This year that class was joined by the class in illustration, and the result was an amazing 74 entries! You could go around the room with eyes closed, poke your finger at the wall, and come up with an excellent design. The judges (one of them a former student who had an entry into our very first competition!) finally came up with five prize winners, and Editors Thum and Gray picked out six more we laymen thought were very good. They will all be on display at the booth at the annual convention in Philadelphia this fall.

A Sturdy Oak

In this column in April 1959 a 92-word definition of metallurgy was given and one of our friends wrote that it sounded more like a telegraphic summary of a year's contents of *Metal Progress*. Indeed this was a compliment to the magazine's coverage! But what brings the topic up again is the fact that the field of metallurgy is not static, praise be; something new, interesting and vital is sure to appear at intervals and dominate the stage. In the Editor-in-Chief's working life there have been at least seven such periods:

Prior to World War I: Improvements in concentration (flotation), smelting and refining (electrolytic zinc, for example).

1914 to 1924: Heat treatment of carbon and alloy constructional steels.

1925 to 1931: Welding (gas and electric) as a production operation rather than merely a method of repair.

1932 to 1938: Corrosion resisting steels and alloys.

1939 to 1945: Two things simultaneously: *(a)* Strong aluminum and magnesium alloys for aircraft and *(b)* low-alloy steels selected for proper hardenability.

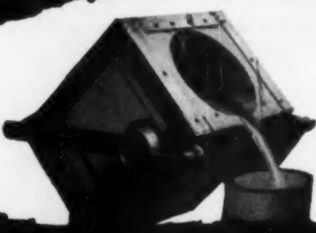
1946 to date: Heat resisting steels, first for jet engines and now for missiles.

1950 to date: Radioactive metals and metals for nuclear devices.

We could of course mention others. In any event one might compare them to vigorously growing branches on a sturdy oak tree. But we on the editorial staff of *Metal Progress* believe that there is one supporting stem which throws off all these branches, and it is variously called metallurgy, metallurgical engineering, physical metallurgy, metals engineering. The sturdy trunk is *metals*; fertilize and water the roots and thereupon branches will spring off as the oak continuously grows. As editors, we must never confuse the branch for the stem.

THE EDITORS

WHY BIG THINGS ARE HAPPENING IN INDUCTION MELTING



Everybody likes change! Particularly the kind of money-saving changes introduced by Inductotherm to induction melting in the past seven years.

To the basic advantages of induction melting, Inductotherm has added features that assure lower costs by simplifying installation, speeding operation, and reducing service requirements.

- Inducto® power feed through tilting furnace trunions cuts the cost of pit construction; saves power losses by reducing cable length.
- Rigid, heliarc welded furnace frame construction improves furnace life and lining life.
- Prepackaged, pretested Inducto control centers take the time, trouble, and expense out of control installation; make start-up swift, sure, and easy.
- The most space-saving induction melting systems ever available are the Inducto "Integral" series, which package motor-generators, capacitors, transformers and all controls *in one compact console!*

Big things are happening in induction melting because Inductotherm is making them happen. But the biggest innovation has been the Inductotherm concept of service. Not just fast repairs and overnight replacement of any parts . . . but the fact that *Inductotherm is in business to fit induction melting to your needs.* We will do everything in our power to improve our equipment and the induction technique, never asking you to trim your requirements to the limitations of our equipment.

If you'd like more information on Inductotherm furnaces, write for Bulletin 70. But, for a taste of Inductotherm service, ask to have an engineer call. Inductotherm Corporation, 412 Illinois Avenue, Delanco, New Jersey.

NDUCTOTHERM

See Us at The FOUNDRY SHOW — BOOTH 224

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Metal Progress

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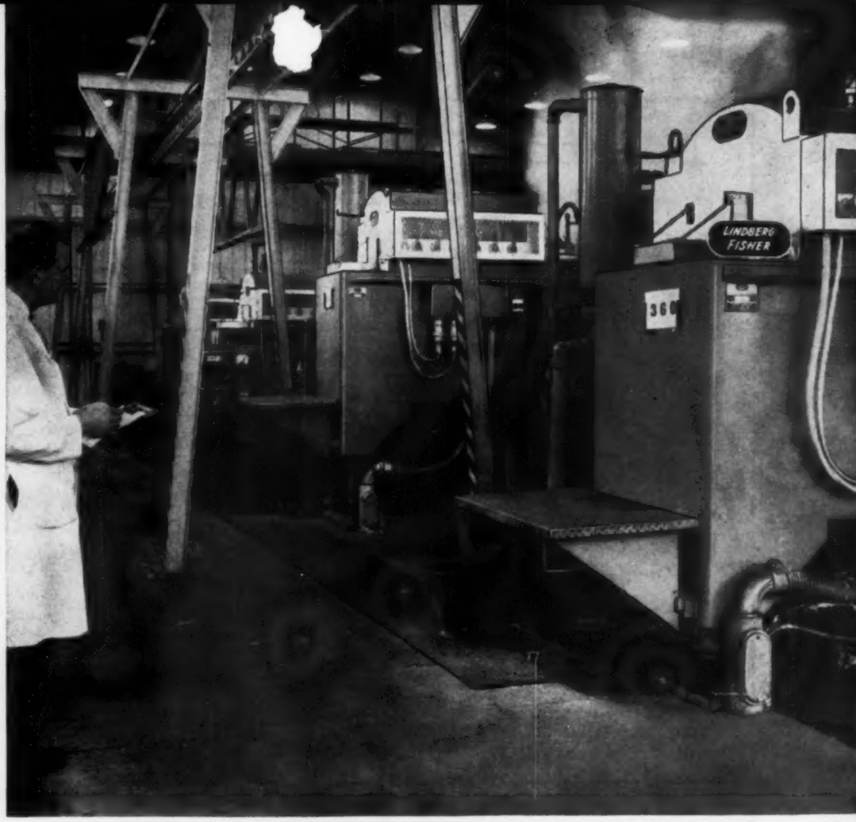
When you apply heat to aluminum Lindberg can give you the right help

If your product requires the application of heat to aluminum, you can safely look to Lindberg for the equipment and methods to do the job best. Anywhere along the line from the ingot to the finished product, Lindberg-Fisher equipment and broad experience can meet every need.

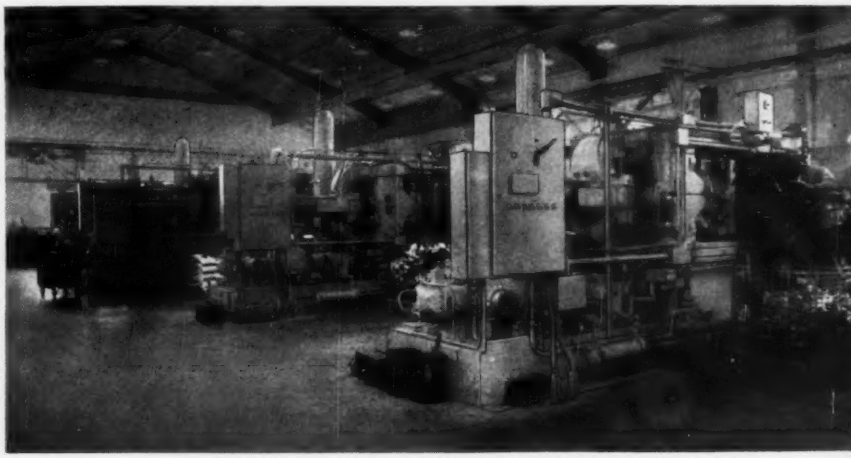
With its long-time background in all phases of heat to industry our engineering staff has standout knowledge of the hows and whys of aluminum melting, casting and treating. Over the years this staff has been responsible for many of the most important developments in the field.

For instance, the technique of putting a cast lining in induction melting furnaces to provide lower initial and maintenance cost . . . the Lindberg Autoladle, the first practical automatic ladling unit . . . the two-chamber induction melting furnace . . . and many other practical innovations. This is why our aluminum processing experts, such as Ray Dunn are frequently consulted in an advisory capacity on aluminum treating problems.

Since we cover all types of equipment for melting, holding or treating aluminum, you can depend upon us to recommend objectively the most suitable procedures and equipment to fit your requirements. Get in touch with your local Lindberg Field Engineer (see your classified phone directory) or write direct to: Lindberg-Fisher Division, Lindberg Engineering Company, 2448 West Hubbard St., Chicago 12, Ill.



Line-up of four Lindberg-Fisher electric resistance reverberatory holding furnaces at McCulloch Corporation. Die casting machines are just behind each furnace.



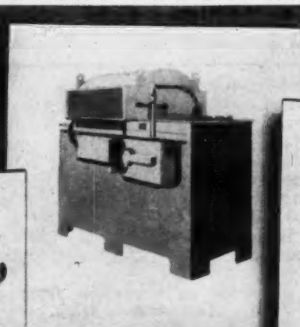
Line-up of four die casting machines at McCulloch Corporation. Lindberg-Fisher Holding Furnaces are just behind each machine.

THERE'S LINDBERG EQUIPMENT FOR EVERY INDUSTRIAL NEED

These are representative units from complete Lindberg lines in all types of industrial heating equipment.

LINDBERG
heat for industry

The Lindberg Autoladle



Electric Resistance Aluminum Holding Furnace

Cyclone Heat Treating Furnace

THE RIGHT COMBINATION FOR DIE CASTING EFFICIENCY...LINDBERG FURNACES AND AUTOMATIC LADLING

Die casting efficiency at the McCulloch Corporation, Los Angeles, California, has been gratifyingly increased with the new installation of four Lindberg Electric Resistance Reverberatory Holding Furnaces equipped with Lindberg's automatic ladling unit, the Autoladle. These holding furnaces, with 2000 lbs. molten aluminum capacity, are spotted adjacent to four die casting machines. Molten aluminum is delivered to the furnaces by monorail and held at the precise temperature required by the casting station. The precise shot is delivered automatically to the die casting machine by the Lindberg Autoladle. This installation is used primarily for casting parts for McCulloch-Scott outboard motors.

In any production process where aluminum needs heat there is Lindberg equipment to apply it most economically and efficiently, and Lindberg experience to fit this equipment most ideally to your product and production requirements. Furnaces for melting and holding, casting stations, re-melting or heat treating are available in all capacities, electric or fuel fired. Get in touch with your Lindberg Field Engineer (see your classified phone book) or write us direct. Lindberg-Fisher Division, Lindberg Engineering Company, 2448 West Hubbard St., Chicago 12, Illinois. Los Angeles Plant: 11937 South Regentview Ave., Downey, California. In Canada: Birlefco-Lindberg, Ltd., Toronto.

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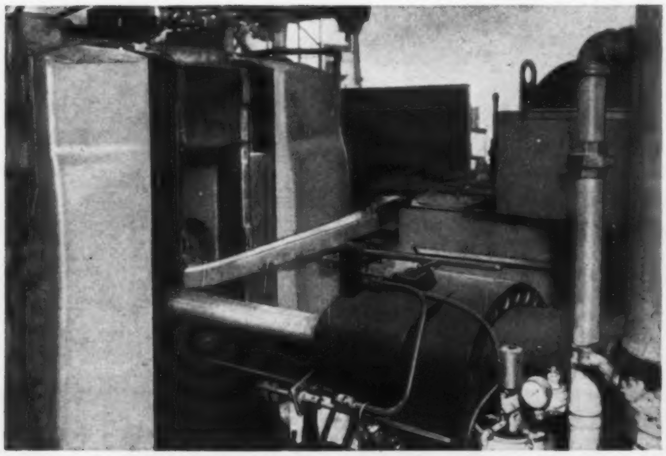
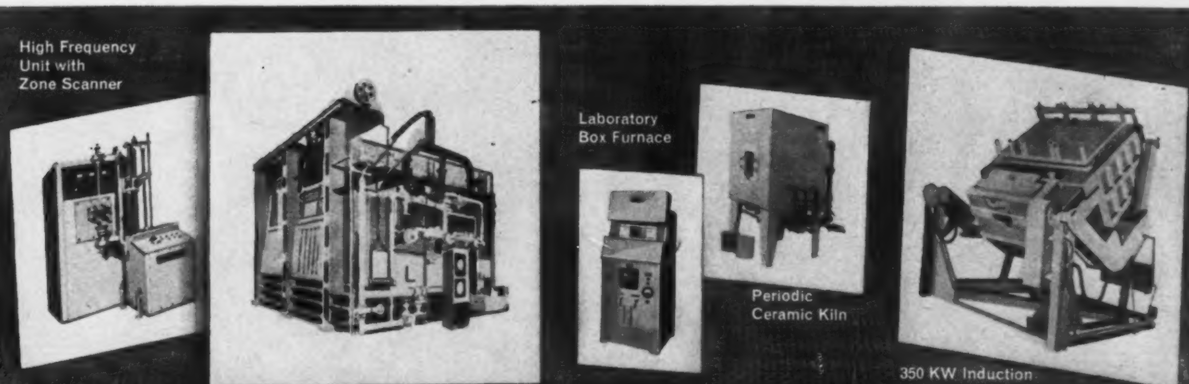


Precise shot of proper temperature aluminum is automatically delivered from conveniently located holding furnace to die casting machine by Lindberg Autoladle.

Housings for McCulloch-Scott outboard motors, shown here, are representative of the type of castings Lindberg equipment helps McCulloch produce.



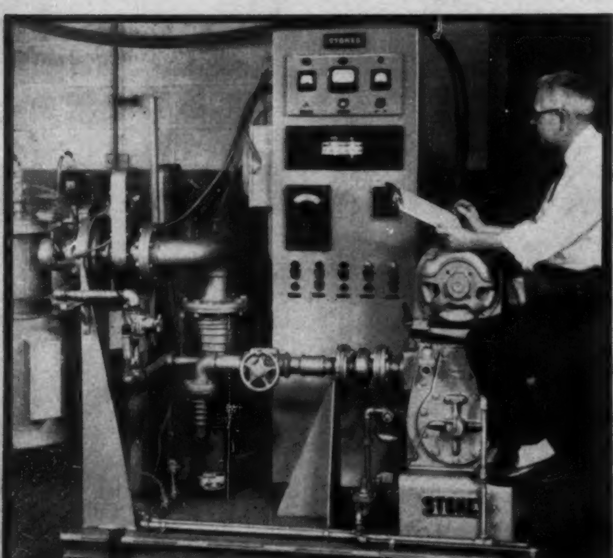
HIGH SPEED PRODUCTION

...a STOKES

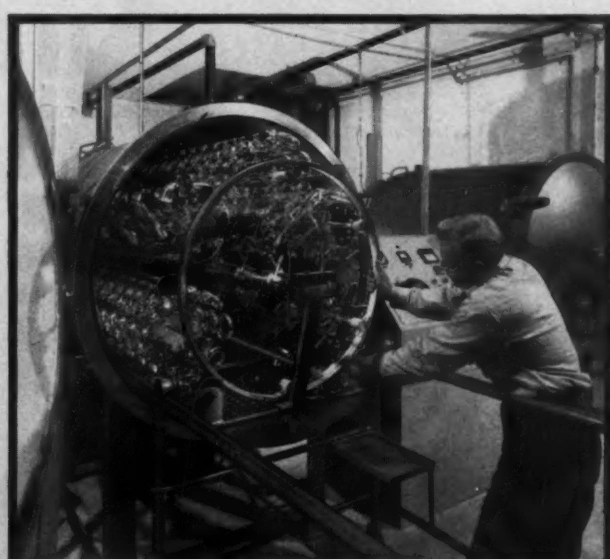
Recognizing the importance of profitable production as soon as possible after prototype proving, Stokes has made high speed an inherent factor in its vacuum metallurgical equipment. With each technological breakthrough, Stokes vacuum engineers intensify their efforts to convert the research accomplishment into a practical and profitable production reality.

From research and development to system installation and operation, Stokes unmatched technical competence and unparalleled experience assure you the most advanced performance in vacuum metallurgy. Stokes led in compressing the time from prototype development to full scale production. Now, Stokes offers

At Associated Spring Corp., Bristol, Connecticut, precision springs finer than a human hair are vacuum heat treated to rigid specifications. Fabricated from critical alloys, they require precise processing. A Stokes Vacuum Furnace enables production of springs for even the most delicate instruments.



Welsh Industries uses two Stokes vacuum metallizers in first and second surface metallizing of a variety of automotive and appliance parts. Because they require less attention, one operator can supervise two Stokes metallizers. Welsh has realized a 20% production increase since installing the Stokes units. The compact size of the Stokes metallizers saves Welsh 10% in floor space.



COUPLED WITH QUALITY

Advance in Vacuum Metallurgy

realistic high speed, profitable production . . . stemming from complete vacuum system engineering. A recently installed Stokes high production furnace has produced over 1,000 heats in just 3 months!

Stokes offers the most complete range of types and sizes of vacuum furnaces and metallizers . . . as well as custom-designed systems. For example, we have demonstrated our capability in supplying a complete turnkey installation—erected, tested and delivered in operation. Result: you profit from a single source of responsibility.

If you have out-of-the-ordinary requirements, we can handle them also. The large majority of special installations throughout the United States are Stokes-engineered. And whether it's a special system or production unit, you get faster delivery and fewer costly holdups.

Let us put our vast experience and complete facilities to work for you. Stokes Engineering Advisory Service will work closely with you in planning and designing an installation that will serve both your present and future needs . . . profitably. May we invite you to contact us directly in order to learn all the facts?

STOKES

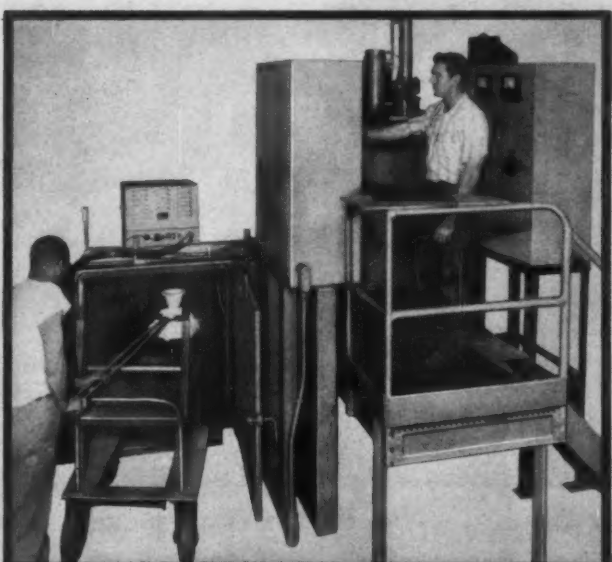
Vacuum Metallurgical Division

F. J. STOKES CORPORATION

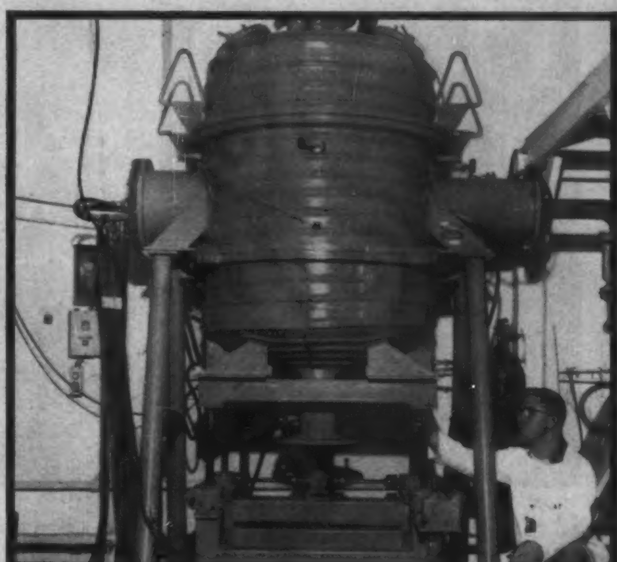
5500 Tabor Road, Philadelphia 20, Pa.

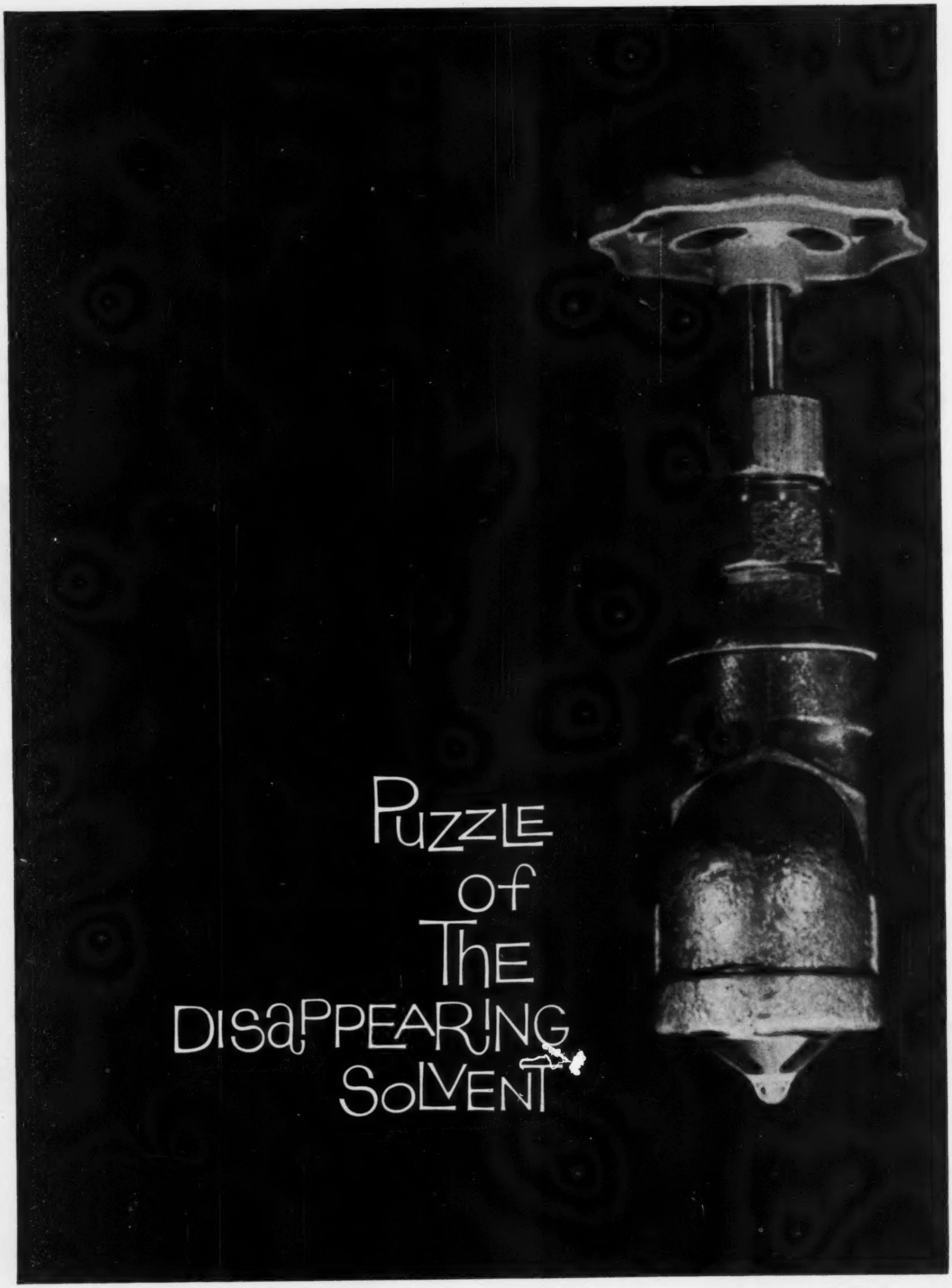
Circle 1788 on Page 48-A

At Misco Precision Casting Co., semi-continuous vacuum melting and casting is being accomplished in two versatile Stokes induction furnaces. Successive charges of the metal can be introduced into the vacuum chamber from the outside, loaded into the crucible, melted, poured, and the cast pieces (in their molds) removed from the chamber . . . all without breaking the vacuum.



Installed at Atomics International, this Stokes 50 KW vacuum furnace is casting long, hollow uranium cylinders to such size tolerances that no subsequent machining is required. For another project, the furnace operates remotely in casting uranium fuel slugs. In both instances, maximum precision must be sustained through tight, large-scale production schedules.




Puzzle
of
The
Disappearing
Solvent

OR how to degrease more parts per dollar of cleaning cost

Every time they needed more vapor-degreasing solvent, the drum was empty, it seemed.

At first it didn't bother them much. Then, suddenly, they realized what was happening to their degreasing costs.

The solvent wasn't lasting as long as it should between bath cleanouts. That's why they had to use so much of it. Worst of all, every time a bath went sour they had to pull the degreaser off the line. That's where the real expense was lurking: in slowed-up production.

PSP TO THE RESCUE They solved the puzzle—with a degreasing solvent that can't wear out prematurely. It has permanent staying power—psp—because it's protected by a stabilizer that doesn't get used up during degreasing.

You stand a good chance of getting lower metal-cleaning cost with this solvent, too. It's called Nialk TRICHLOR. You don't have to add fresh stabilizer to it. Even when you distill the solvent, it remains stable. Even the vapor is stabilized. And you use less solvent, because less goes down the drain in unnecessary cleanouts.

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HOOKER CHEMICALS PLASTICS

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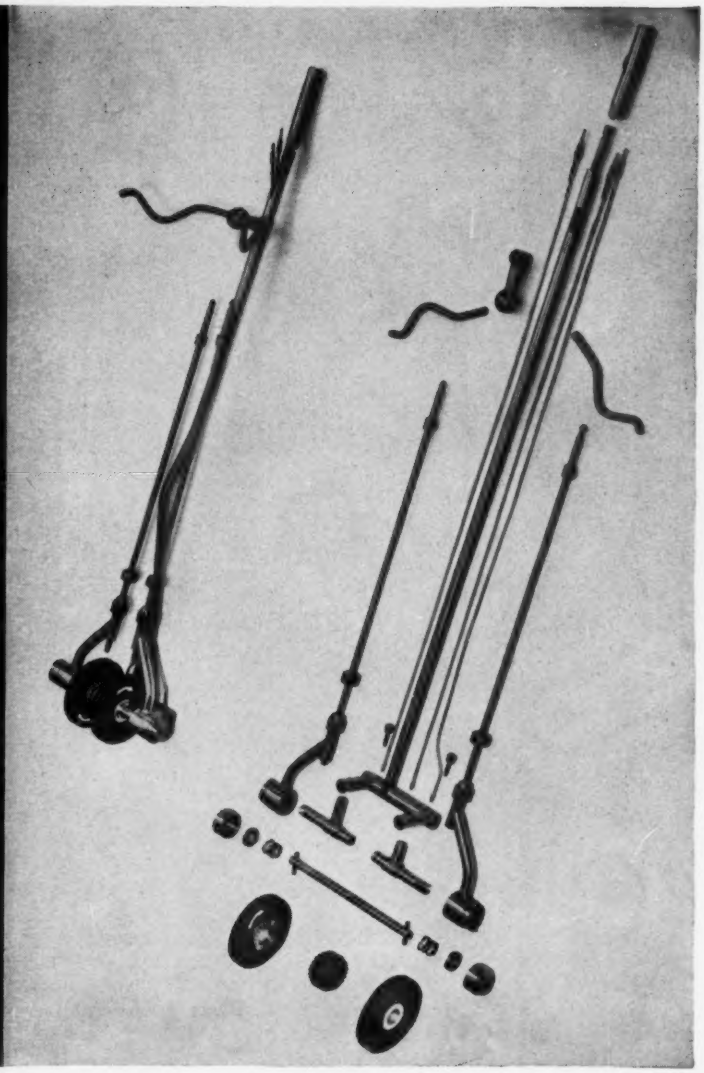
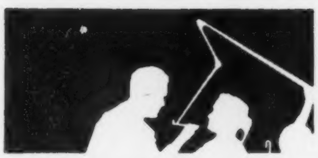
HERE'S HOW STILL ANOTHER MANUFACTURER JOINS STAINLESS STEEL TUBING:

He uses Handy & Harman's BRAZE 630





He's one of many manufacturers and fabricators who have found—to their lasting satisfaction—that Handy & Harman silver alloy brazing is the final answer to stainless steel joining problems.

Super-Donic Manufacturing Company, Atlanta, Georgia, manufactures "Dual Arm Transmissions" for the dental industry. Most everybody has—at one time or another—seen and/or felt this unit in operation.

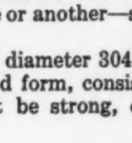
It is fabricated of small diameter 304 and 316 stainless steel tubing and, in its assembled form, consists of some 17 separate brazed joints. Joints must be strong, corrosion resistant and neat-appearing.

Each of the 17 joints is hand-torch brazed with Handy & Harman BRAZE 630 wire and HANDY FLUX TYPE B-1. There's no question that this is a unique application. There's no question, either, that the application is stainless steel. The ease and economy with which this manufacturer solves his problems can be just as readily applied to *your* stainless steel joining problems.

Strength, production speed, electrical and thermal conductivity, gas and liquid tightness and low cost are *natural* benefits of silver alloy brazing. We think it worth your while to learn more about this remarkable metal-joining method—we'll be glad to send you any information you ask for. Handy & Harman, 82 Fulton St., New York 38, N. Y.

FOR A GOOD START: BULLETIN 20

This informative booklet gives a good picture of silver brazing and its benefits . . . includes details on alloys, heating methods, joint design and production techniques. Write for your copy.



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Circle 1790 on Page 48-A

Meets precise metallurgical standards in carburizing, carbonitriding, neutral hardening, sintering, normalizing, annealing and brazing.

- Each zone with individual 100% forced convection heating!
- Silicon carbide skid-type hearth fully supports light-weight trays.
- Super-alloyed ceramic tubes guaranteed one year. Ipsen "Flame-Busters" complete combustion within the heating portion of the tube.
- Both forced convection atmosphere cooling and hot-oil quench.
- Ipsen pusher units are shipped completely piped, wired, and tested.

Cross-section diagrams and complete details covering all sizes of Ipsen pusher units are shown in Bulletin P-59. Send for your copy, today.

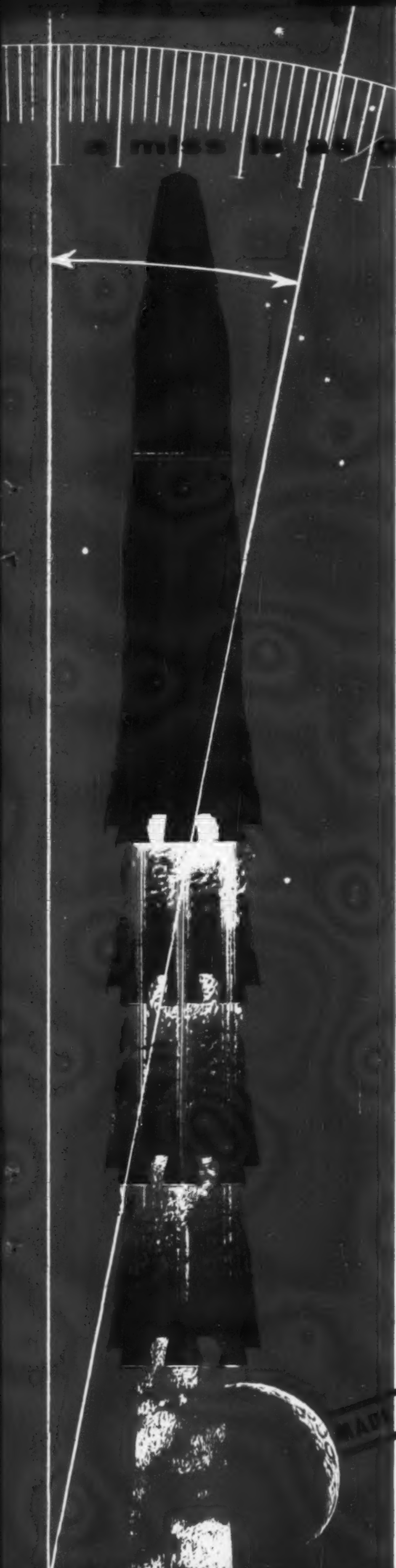
*special units available for higher temperature operation

AUTOMATIC Ipsen HEAT TREATING UNITS

IPSEN INDUSTRIES, INC. • 723 SOUTH MAIN STREET • ROCKFORD, ILLINOIS

Circle 1791 on Page 48-A

Circle 1792 on Page 48-A



® gives you fault-free metals for **high speed** fabrication

Advanced mill processes — Scovill pioneered the CONTINUOUS CASTING of Brass alloys to bring fabricators of Brass Mill Products the new standard of metal soundness and uniformity made possible by this unique process. Other more recent new mill installations at Scovill include precision-controlled Aluminum rolling mills; the advanced Sendzimir Mill for extra-close-tolerance sheet and strip; the World's largest vertical tube extrusion press, with automatic induction billet-heating equipment, as well as one of the Industry's newest and largest specialized tube mills.

Advanced quality-control procedures — insure dependable UNIFORMITY in all Scovill Mill Products specifications . . . order to order and lot to lot. They promise more accurately dimensioned, finer quality mill products essential to efficient high speed fabrication. Quality-control is a full-time job at Scovill, and the results are evident to fabricators in their own higher production speeds, minimum tool and machine adjustments and superior quality of finished products.

Advanced inspection equipment and methods — There are many inspection stations along each of the Scovill production lines for Brass strip and sheet, rod, wire and tube. In addition, samples of alloy billets and bars, as well as of finished mill products, undergo detailed inspection and test procedures in Scovill's Metals Research laboratories. Brass Mill Products that pass these rigid inspections and tests are considered by many to be the finest in the World.

Advanced packaging — Unique Scovill packaging methods protect quality, finish and condition, make it easier for fabricators to warehouse, handle and use Mill Products. Time- and cost-saving innovations such as extra-long-length coils of strip, self-feeding wire "dispenser" drums, special long lengths when required in tube mill products, are available to fabricators who need them.

Make Scovill a part of your competitive team, let us contribute our wealth of experience and ultra-modern equipment to the success of your NEW products and production plans.

SCOVILL MANUFACTURING COMPANY

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MADE IN USA

. . . and made better to bring out the BEST in your products

MILL PRODUCTS

7SC60

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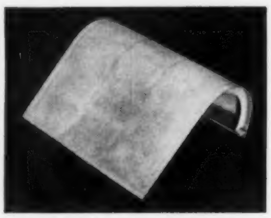
Report on Developments of

New Fansteel 82 Metal in Hypersonic Vehicle Prototypes

Design and development work on hypersonic flight vehicles by Boeing Airplane Company and other missile and airframe manufacturers has indicated some important use-possibilities for Fansteel 82 Metal. This new columbium-tantalum-zirconium alloy was among the materials fabricated into prototype leading edges for materials capability evaluations at 2000°F and over. Results verified Fansteel's own tests proving the metal's high strength-to-weight properties at elevated temperatures.

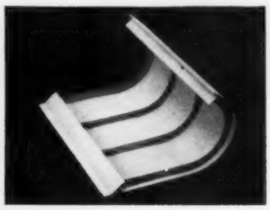


Excellent Oxidation Resistance

Exhaustive tests in the Fansteel laboratories prove Fansteel 82 Metal far superior in oxidation resistance to pure columbium. Calculated on the basis of weight gain during exposure at 2000°F in air, 82 Metal is ten times as resistant as the pure refractory metal. Sixteen-hour, 2000°F test in flowing air showed remarkable low scaling of 0.01 cm.

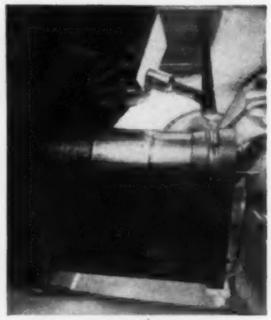
Tensile Properties of Sheet

The encouraging results of Boeing's prototype tests indicate 82 Metal's suitability for airframe and missile material. Average tensile properties are shown below.



Fansteel 82 Metal Easily Formed

In addition to its high temperature properties, 82 Metal has excellent fabricating characteristics. Ductile welds are made with little or no tendency to fracture in heat affected zones. It is easily fabricated at room temperatures, as worked or annealed. Its melting point is 4550°F and density 10.26 grams per cc (0.371 lb. per cu. in.).



Welding the Boeing prototype in an inert atmosphere chamber using tungsten inert gas process.

Design and Engineering Help

Fansteel engineers and metallurgists are now working with many other firms in adapting Fansteel 82 Metal to specific areas. They will be glad to cooperate with your own designers and production people in studying and applying this useful new metal. Just send us your print or part sample, or call in the Fansteel representative.

Available From Stock

For experimental purposes . . . Fansteel 82 Metal is available from stock in ingots, forgings, bar, rod, plate and sheet. Let us keep you informed of developments concerning this new alloy as they occur. Write for the latest technical bulletin.

TENSILE PROPERTIES OF SHEET

TEMPERATURE Degrees F	ATMOSPHERE	ULTIMATE TENSILE STRENGTH, psi.	YIELD STRENGTH .2% offset, psi.	ELONGATION % in 1 in.
70-80	Air	76,000	65,000	12
1800	Argon	59,000	53,000	1.5
2400	Argon	19,000	15,000	14

Photos Courtesy of Boeing Airplane Company

FANSTEEL

FANSTEEL METALLURGICAL CORPORATION
NORTH CHICAGO, ILLINOIS, U.S.A.

K602

Circle 1746 on Page 48-A

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
[illegible]

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Pack Hardening Tools? Be Sure to Use a Thermocouple

When pack hardening tools to reduce scaling and decarburization, it's a good idea to place a thermocouple in the pack, against the tools, to check accurately the time the tools are at heat. Failure to do so may lead to trouble.

For example, an experienced heat-treater pack hardened a large-diameter die ring made of Bethlehem Lehigh H tool steel. Then he checked the hardness. Imagine his surprise to find it was only Rockwell C-48. Puzzled, he checked the furnace pyrometer charts. They showed that the recommended heating cycle had been followed. But why such a low hardness?

A Bethlehem contact metallurgist suggested that the die ring be rehardened, and that a thermocouple be inserted in the pack against the ring. After this was done, and the cycle repeated, the hardness jumped to Rockwell C-60. It was noted that the time required to heat the tool was 50 pct greater than in the first cycle. Thus the heat-treater had proof that in the initial treatment, the die ring was not heated long enough to reach proper temperature, despite the fact that the furnace pyrometer apparently indicated the correct heating cycle.

Fabricator Reduces Punching Costs by Changing to Omega Tool Steel

This picture, taken at Dave Steel Co., Asheville, N. C., shows Bethlehem Omega tool steel punching a ½-in. diam hole in a structural angle about ⅜-in. thick. The fabricator reported that the Omega performed as though the structural steel were so much butter. It produced thousands of clean, burr-free holes of uniform size, resulting in an 18 pct reduction in punching costs, as compared with the grade formerly used.

Omega is our "super" grade of oil-hardening, shock-resisting tool steel. In addition to being a long-wearing grade, Omega offers maximum shock-resistance for hardnesses up to Rockwell C-59.

Omega tool steel can be quenched in oil at 1625 F. It also offers the advantage of water quenching from 1550 F.

TYPICAL ANALYSIS

C	Mn	Si	Mo	V
0.60	0.70	1.85	0.45	0.20

Besides its use in punches, Omega is also ideal for calking tools, beading tools, shear blades and chipping chisels—in fact, any severe service involving drastic and repeated impact.

If you would like full details on Omega tool steel, get in touch with your Bethlehem tool steel distributor.

Circle 1747 on Page 48-A

Upset-forged Discs Are Easy To Machine

Bethlehem upset-forged discs, made of Cromo-WV (H-12) tool steel, are ideal for aluminum extrusions tooling because of the basic 5 pct chrome analysis. They are also economical because of their easy machinability, and ease of heat-treatment. They're made with exacting care, and are finished in ring dies to insure good section and sharp edges. Moreover, Cromo-WV has good resistance to washing and heat checking.

Circle 1748 on Page 48-A

NEW PRODUCTS

Ferrous Metals

Color-Coated Steel Panels

Ridged, galvanized, 26-gage steel is the basis of color-coated steel panels for curtain walls and other architectural details. Sheets are 36 in. wide and any length specified. Nine colors are available, chosen by an automotive styling expert to appeal to modern tastes. Several coats of a vinyl-base color or aluminum coating are topped off by a clear adhesive coating. *Stran-Steel Corp.* says the baked color won't chip, peel or fade.

For further information circle No. 1450 on literature request card, p. 48A and B.

Nonferrous Metals

Aluminum Alloy of High Machinability

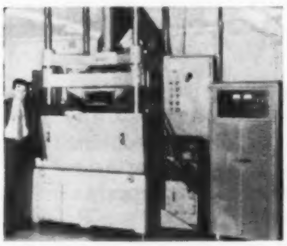
An extensive research into the machinability of aluminum alloys by *Kaiser Aluminum & Chemical Corp.* has led to the marketing of an improved 2011-T3 alloy, tradenamed "Micro-Chip". Extensive field tests show that it produces smaller and finer chips and with longer tool life in 90% of the trials made to compare it with conventional 2011-T3. The parts have a consistently bright and clean appearance. Stock is color-coded on both ends.

For further information circle No. 1451, p. 48A and B.

Cutting and Forming

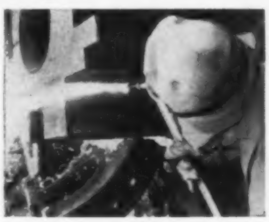
Electrical Discharge Machining

The engraving shows an "HM-650" machine with portable and detachable power supply for sinking shapes in forging dies by "electrical discharge machining" at the unprecedented rate of 20 cu.in. per hr., – so fast indeed that an efficient exhaust system must carry away the iron oxide smoke. The electrodes are of an improved aluminum alloy which wear, it is said, at less than one-eighth the rate of conventional electrodes. The "ER-300" power supply shown is for rapid and rough machining to within 0.06 in. of the final contour, whereupon it is wheeled away and replaced with an "Elox NPS" finishing power supply without moving the die or other parts of the set-up. *Elox Corp. of Michigan.*



For further information circle No. 1452 on literature request card, p. 48A and B.

Cutting Torch

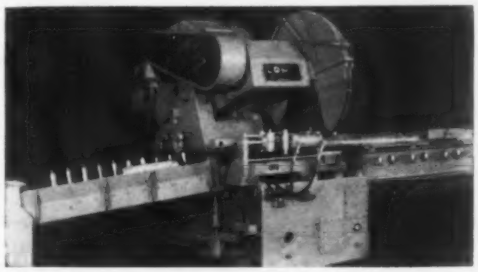


Several new features characterize a rugged cutting torch for heavy duty – up to 24-in. steel. Large tubes and valves supply ample gas. Oxygen can be gradually increased to avoid spraying of slag and to control the cutting process with depth. A set of tips, which slip into place without needing a wrench for tightening, are included, so the equipment can use several kinds of fuel gas. Light (3 lb., 10 oz.) and well balanced, the head may be 75° or 90°, and the length 21 or 36 in. *Smith Welding Equipment Corp.*

For further information circle No. 1453 on literature request card, p. 48A and B.

Billet Cut-Off

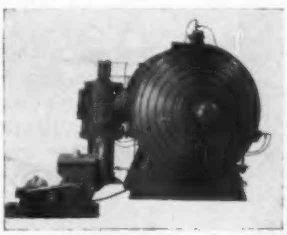
Aluminum alloy billets up to 16 in. diameter may be rapidly cut in an automatic cycle of operations on the *Loma Machine Mfg. Co.'s* equipment. The saw, 48-in. dia., is driven by a 75-hp. motor, both tilted by a hydraulically operated arm, and swung in such a way that the pressure is taken by the rugged base, thus eliminating chatter and insuring an unusually smooth cut. Chips and coolant are thrown to receptacles at the rear and removed by conveyers and drain. Feed table, stop, clamp, saw, and run-off table operate by program control.



For further information circle No. 1454 on literature request card, p. 48A and B.

Industrial Heating

Vacuum Heat Treatment



A rear view is shown of a high-vacuum furnace (Series V-5-750) with work space 26-in. cube and 200-lb. capacity, made by *Ipsen Industries.* The door on the other end is hinged at the side and has a peep hole. The vacuum equipment is a 120-cu.ft. per min. mechanical pump, and a 16-in. vapor diffusion pump; 20 min. is required to reach 1 micron. Power panel (not shown) also contains controls whereby the complete heat treating cycle may be set to operate automatically. The hearth is of molybdenum and the heating elements are graphite. The work is cooled by a vacuum-sealed fan within the casing which blows inert gas on the work; maximum load cools from 2600° down to 400° F. in 90 min.

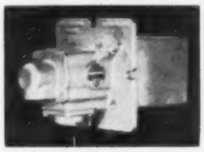
For further information circle No. 1455 on literature request card, p. 48A and B.

High Frequency Generator

Lindberg Engineering Co. has designed a 10-kw. high-frequency unit completely enclosed in a 40-in. square, 6-ft. high cabinet, weighing 2150 lb. It takes 3-phase, 60-cycle current at 230 or 460 volts and delivers currents at either 400 or 4000 kilocycles per sec. at separate output terminals, one of each pair being at ground potential. Two mercury-vapor rectifiers on each leg of the 3-phase input supply power to a water-cooled oscillator tube. This in turn feeds a sealed tank capacitor containing a liquid dielectric for the 400-kilocycle system, and vacuum capacitors for the 4000-kilocycle system. Among the auxiliaries is a system of neon lights which indicate any abnormality in the protective devices.

For further information circle No. 1456 on literature request card, p. 48A and B.

Gas Burner



Series 4423 Sealed-In Nozzle Mix Burner operates on constant air supply but the gas may be varied either manually or by automatic controllers. For example, the largest size (1½ in.) can have its fuel turned down from 431 cu.ft. per hr. to 52; the air pressure remains constant at 16 ounces. This results in a reduction of heat from 430,000 Btu. to 3000 in a furnace at 675° F; at the low point the flame is entirely within the hollow tile block, and the hot gases going through the pores are at about 700° F. Flame monitoring devices, either a constant or interrupted pilot, may be installed. *North American Mfg. Co.*

For further information circle No. 1457 on literature request card, p. 48A and B.

Cleaning & Finishing

Testing of Finishing Qualities

A machine was designed in 1957 for a research program of the American Electroplaters Society which proved so successful that a model for commercial operations is now being made by *Acme Mfg. Co.* As shown in the view, 5 x 12-in. samples of plated ware are attached to a conveyor which moves horizontally under a buffing wheel of any desired diameter, running at any desired speed (oscillated or not) and pressing at any desired force. Buffing compounds and vehicles are sucked from the cabinet. Horsepower required, plus a study of the finish, evaluate the results.

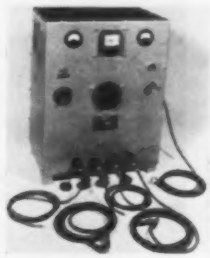
For further information circle No. 1458 on literature request card, p. 48A and B.

Emulsion Cleaner

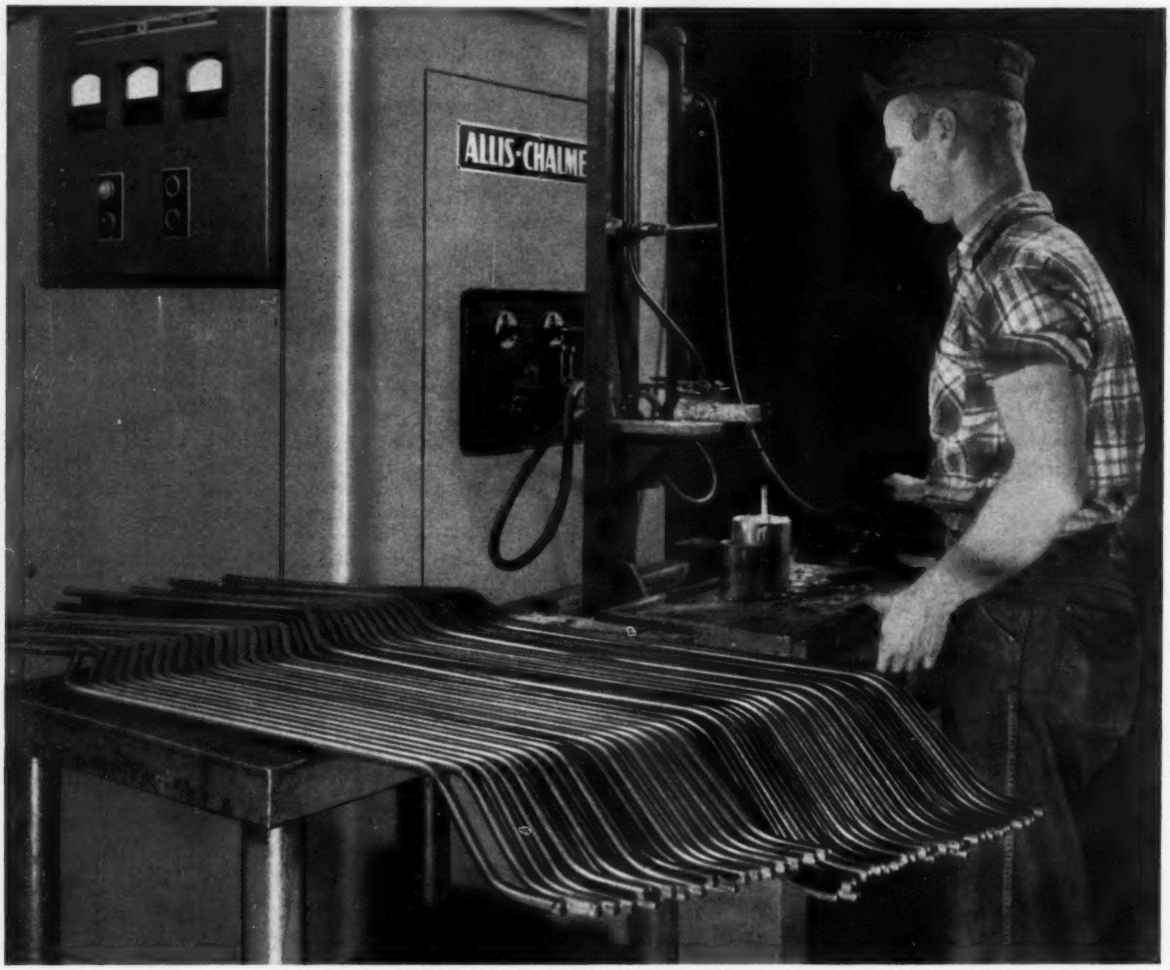
Steel – and in fact most metallic alloys – can be cleaned of dirt and heavy oil films during immersion from a few seconds up to 10 min., depending on circumstances, in a cold solution of "Heatbath Emulsion Cleaner No. 1". All that is then necessary is a water rinse (by pressure spray if dirt is heavy) which emulsifies the solution carried out and leaves behind a clean metallic surface, usually suitable for plating, phosphating and blackening without further ado. There is no bad odor; the cleaner also withstands contamination excellently. *Heatbath Corp.*

For further information circle No. 1459 on literature request card, p. 48A and B.

Spot Electroplating



A small cabinet weighing only 225 lb. contains a power pack for two electroplating circuits. It plugs into any 220-volt, 60-cycle, single-phase circuit, and can deliver direct current to two circuits, each variable from zero to 50 amperes and from zero to 30 volts. One lead – the cathode of each pair – clamps to the work; the anode has a stylus wrapped with cotton saturated



Allis-Chalmers induction heater brazing hydraulic tubing to oil pump. Operation is accomplished in seconds.

Circle 1750 on Page 48-A

with the desired plating solution. A variety of the metals commonly used for protective or decorative finishes may thus be deposited on selected areas without immersing the part in a tank or without extensive masking. *Sifco Metachemical, Inc.*

For further information circle No. 1460 on literature request card, p. 48A and B.

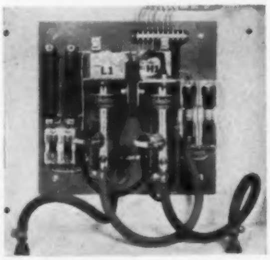
Welding & Joining

Non-Spatter Electrode

A. O. Smith Corp. has worked up a new electrode similar to the widely-used E 6012 for steel, called "SW 612" with a coating high in rutile and which, at high-current, high-speed operation, especially on poorly fitted joints, reduces spatter loss by 60% and increases deposition efficiency by 15%. The bead has a good-looking, high convex crown which increases its crack resistance. Time for slag removal and clean-up is reduced at least 50%.

For further information circle No. 1461 on literature request canrd, p. 48A and B.

"Spike Power" Welding

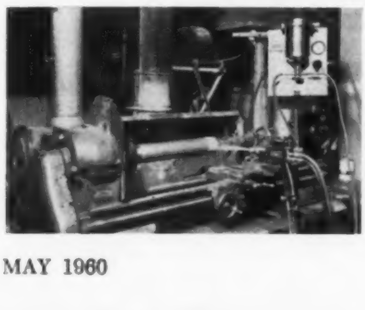


A new co-axial ignitron tube contactor, capable of safely handling very high currents for very short times, can make resistance welds without the large transformers conventionally necessary. It is said to combine all the advantages of ordinary resistance welding, capacitor discharge welding and percussion welding with none of their disadvantages. Since minimum heat is generated between pulses, the electrodes remain cool, weld markings are minimum – almost non-existent – and the heat is confined to the interface contact area where it forms the weld "button". The equipment is especially adaptable to the spot welding of aluminum and its alloys. *Robotron Corp.*

For further information circle No. 1462 on literature request card, p. 48A and B.

Spraywelder

The *Wall Colmonoy Corp.'s* "Spraywelder Unit" – basically hand-operated, but with an attachment for mounting on a lathe-tool post – features high production of 12 lb. per hr., 95% of which is deposited on the work. It consists basically of a pistol, a hopper and a control panel. Mounted on the panel are the powder hopper with carburetor plus an air dryer, filter and regulator. The unit uses oxygen and acetylene and air as a powder propellant, which deposits a solid, nonporous overlay on the workpiece. The air also cools the pistol's head and tip, resulting in longer life in service.



For further information circle No. 1463 on literature request card, p. 48A and B.

Inspection & Control Equipment

Compact Spectrophotometer

A complete instrument with recording device, occupying only 3 ft. of bench space, features a fast-acting chart. This rotates rapidly until a complex spectrum appears, whereupon it instantly slows down so the pen can record every detail. This results in a minimum of time for complete scanning. The small house for dual lamps at the right side is so designed that the flip of a lever brings into action either a hydrogen, a tungsten or a mercury lamp with sharp, narrow lines in both the ultra-violet and the visible spectra. Range extends from 200 mu in the ultra-violet to 700 mu at the red end. Two gratings, each with 1200 lines per mm., give very high dispersion and great resolving power. *Bausch & Lomb Optical Co.*

For further information circle No. 1464, p. 48A and B.

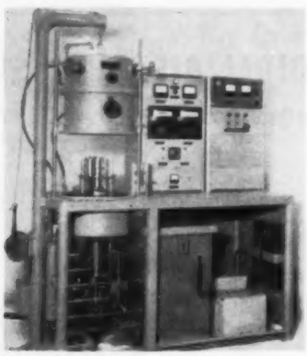
Multipoint Recorder

The "Honeywell Universal Model 15 ElectroniK Recorder" is arranged so measurements can be switched from two points to any number up to 24, merely by changing a plug connection and twirling a printing wheel. In this way, the temperature at any one of two dozen locations can be spot checked, or recorded for any desired length of time to verify its uniformity or discover any drift. Chart ranges and scales can also be adjusted to specific needs. These universal models also measure, interchangeably, potentiometer circuits or resistance thermometers. *Minneapolis-Honeywell Regulator Co.*

For further information circle No. 1465 on literature request card, p. 48A and B.

Hot Hardness Tester

Vacuum Specialties Co. offers a self-contained unit for making single or multiple hardness tests at temperatures up to 2850° F. and vacuums down to 10^{-5} mm. Hg. The view shows the chamber in the raised position, exposing the tantalum resistor for heating the sample. The cylindrical heat shield (split longitudinally, one half standing at the side) is a series of tantalum and stainless steel sheets.



The sample to be tested rests on the round molybdenum base, shown just above the bench-top. The indenter is a sapphire point on a molybdenum rod with a 2-kg. weight. This assembly is mounted on a cross feed table with micrometer adjustments, operated from outside the vacuum chamber, so a great many closely spaced indentations can be made on the sample without losing temperature or vacuum in the container.

For further information circle No. 1466 on literature request card, p. 48A and B.

Platinum-Clad Ware

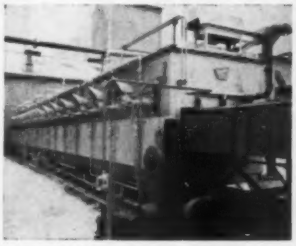
Platinum ware has been used for generations by laboratory men when handling violently corrosive solutions

or making high-temperature ignitions. However, the pure metal is not very strong or stiff, it is costly, and it has a tendency to stick to light fingers. *Fisher Scientific Co.* is now producing such ware of tri-metal, wherein a 0.033-in. sheet of stainless steel is metallurgically bonded on both faces to 0.002 in. of platinum. Edges are protected by rolled-over platinum cladding. Cost is about one-third of solid platinum, and the new ware can be used at temperatures up to 1000° F.

For further information circle No. 1467 on literature request card, p. 48A and B.

Production Equipment

Long Sintering Furnace



Freeport Nickel Co.'s Louisiana plant needed a furnace to sinter 8800 lb. per hr. of nickel briquettes. *Drever Co.* figured that the furnace would need to be 156 ft. long and 10 ft. wide. There seemed to be no reason for housing any part of it except the loading and discharging ends. It is heated by natural gas in radiant tubes, and is gas tight for controlled atmosphere. The briquettes are carried through heating, sintering and cooling zones on a continuous mesh belt, resting on driven rollers. One panel board at the charging end controls all operations.

For further information circle No. 1468 on literature request card, p. 48A and B.

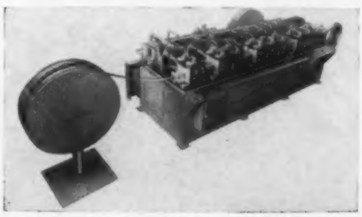
X-Ray Thickness Gage

Westinghouse Electric Corp. has installed an X-ray gage for controlling thickness of aluminum foil as it is rolled on a 4-high cold mill. The gage operates as the foil passes from the rolls to the take-up reel and feeds a signal to the control when the thickness deviates from that desired. This control adjusts the speed of the rolls, and thereby influences the coefficient of friction between foil and rolls, as well as the strip tension. This system can control the accuracy of 0.00035-in. foil aluminum (rolled in doubles) to within 1.5%.

For further information circle No. 1469 on literature request card, p. 48A and B.

Strip Mill Without Housings

A nine-stand strip mill only 10 ft. long for 32-in. aluminum or steel strip is shown in the view. Speed may be 1000 ft. per min. Instead of using housings to hold the roll necks and bearings, the bearing blocks are pulled together by hydraulic cylinders placed in the unit's base. While the hydraulic loading determines the pinch each set of rolls exerts on the strip, the gap can be increased as desired by synchronized screws. Rapid opening, for threading a new strip or for clearing the rolls, is done by hydraulic action. *Production Engineering Co.*



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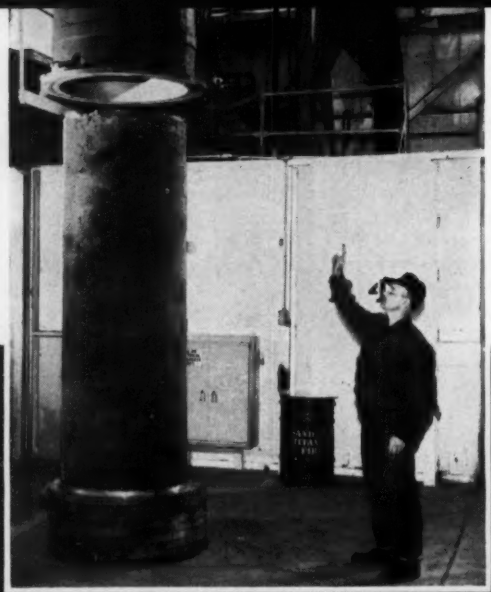
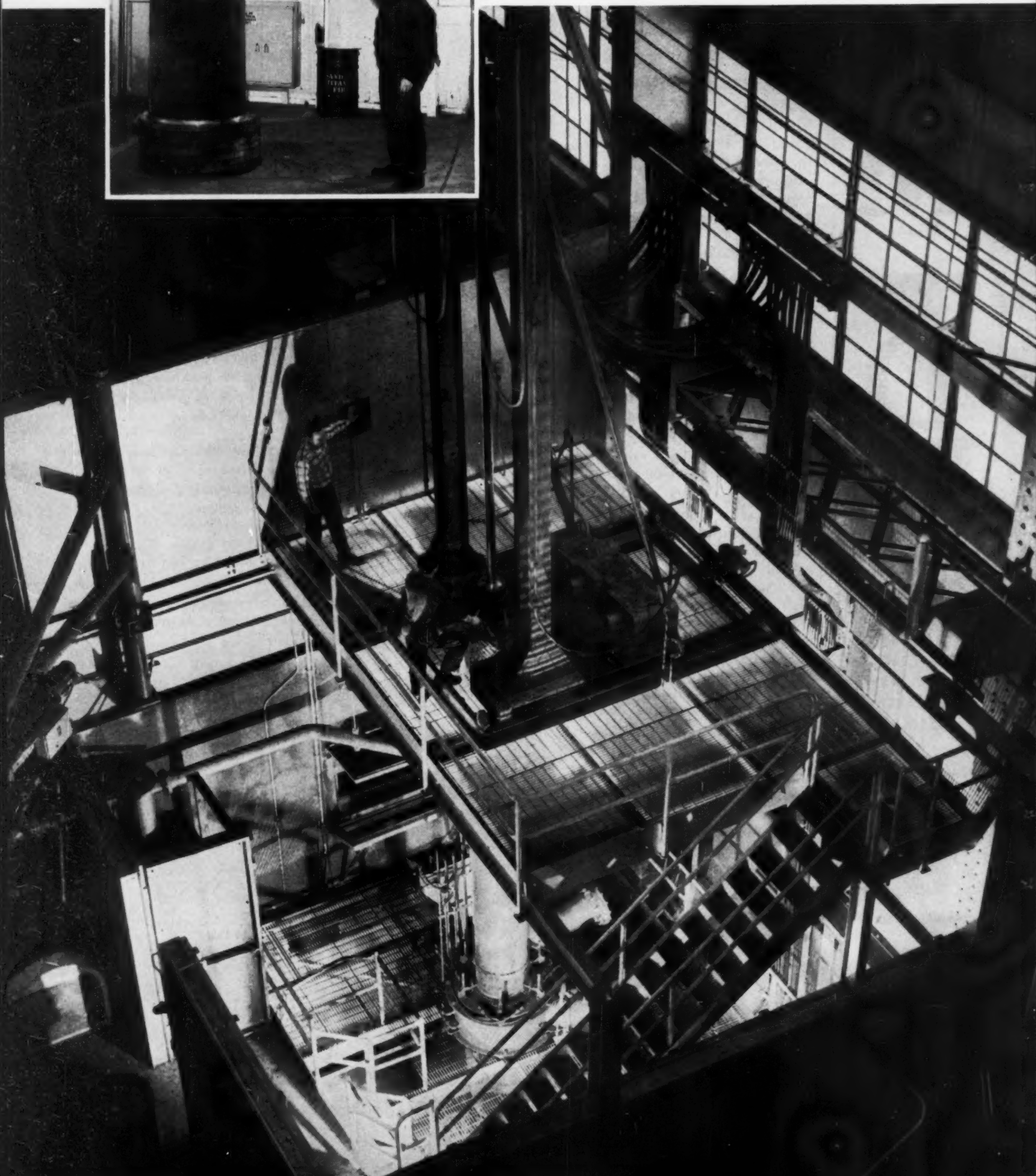


Reliable Quality . . .



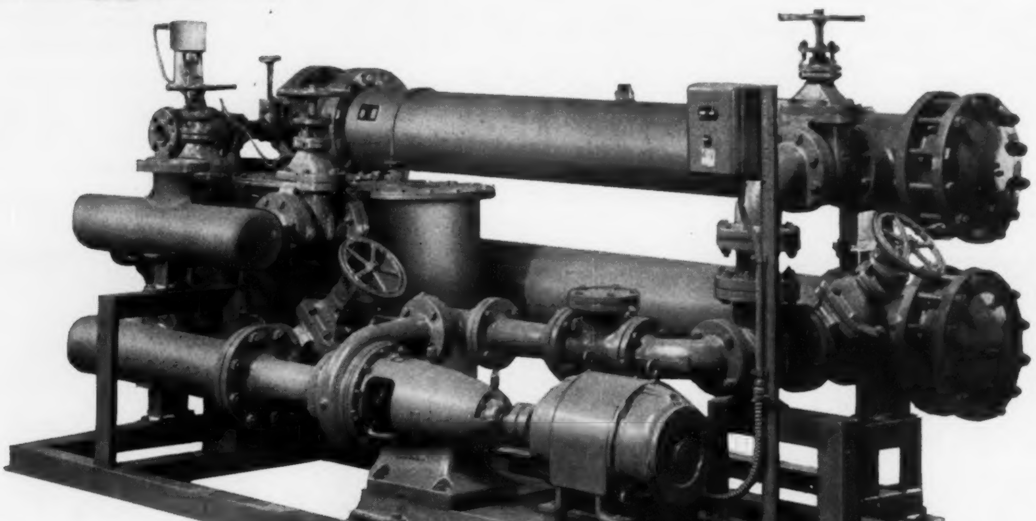
HOW MUCH IS *Faulty Quenching* COSTING YOU?

The quenching stage of your heat-treating process is the point which determines . . . (1) the final quality of your product . . . (2) the amount of time and material wasted by below-standard rejects . . . and (3) your ultimate operating costs.

You can protect yourself against needless production losses by installing a B & G Self-Contained *Hydro-Flo* Oil Cooler. This unit will provide the accurate control of conditions in the quench tank which assures *uniform quality* in the finished product.

The generous heat transfer surface in B & G Self-Contained *Hydro-Flo* Oil Coolers provides large capacities in comparatively small, compact units. They are completely factory assembled, ready for immediate installation and operation.

Tell us about your quenching problems—we'll be glad to offer engineering counsel and recommendations.



Completely Self-Contained Units

B&G *Hydro-Flo* Self-Contained Oil Coolers combine Coolers, Motors, Strainers and all controls into single, integrated, easily installed "packages". Fully automatic, they keep oil temperature at the desired degree through all stages of the quench. Your only responsibility is to connect to the quench tank and water lines.

B&G Oil Cooling Systems may also be purchased as component parts for assembly on the job.

This combined Catalog and Selection Manual gives full information on B&G Self-Contained Oil Coolers. Send for your copy.

Reg. U.S. Pat. Off.

Hydro-Flo
OIL QUENCHING SYSTEMS

BELL & GOSSETT COMPANY
Dept. GE-16, Morton Grove, Illinois

Canadian Licensee: S. A. Armstrong Ltd., 1400 O'Connor Drive, Toronto 16

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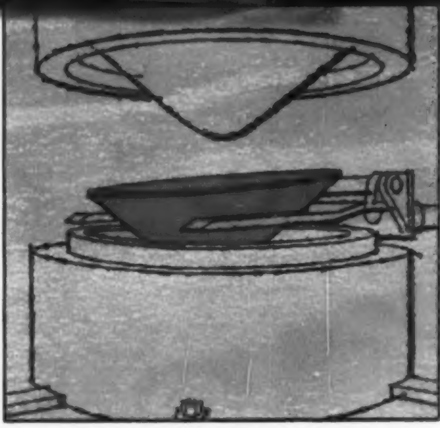

Nose cone being removed from Wyman-Gordon-U.S.A.F. forging press.

Precision Forging of ATLAS Nose Cones

Inspection of copper nose cones at Wyman-Gordon-U.S.A.F. Plant.

When you need a large, custom-engineered die block, think of U. S. Steel first. Take this 40-ton die block shown in the final stage of forging on our 10,000-ton press. Designed by Wyman-Gordon for production of copper nose cones by closed die forging, this job received the personal attention of our metallurgists, forgers, and machinists from start to finish.

To obtain the correct hardness, our metallurgists chose a CrMoV alloy. An 85-ton electric furnace heat was then "vacuum-cast" into a 72" diameter ingot to produce the best internal quality possible. Under the careful supervision of our forge team, the ingot rapidly assumed the final contours. As you can see, the die impression was "forged-in" with a special cupping tool for maximum toughness.

This die block was then subjected to a series of heat treatments and machining operations, closely coordinated between heat-treater and machinist, to produce maximum performance at the Wyman-Gordon-U.S.A.F. Plant. Final inspection of the rough machined block included hardness and ultrasonic testing as well as a close check of dimensions.

In addition to large die blocks such as this one, U. S. Steel makes many types of forgings—all by a team of experts. Let them handle your next order. You'll be assured of a high quality product, specifically engineered for your particular application.

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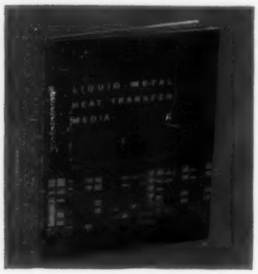

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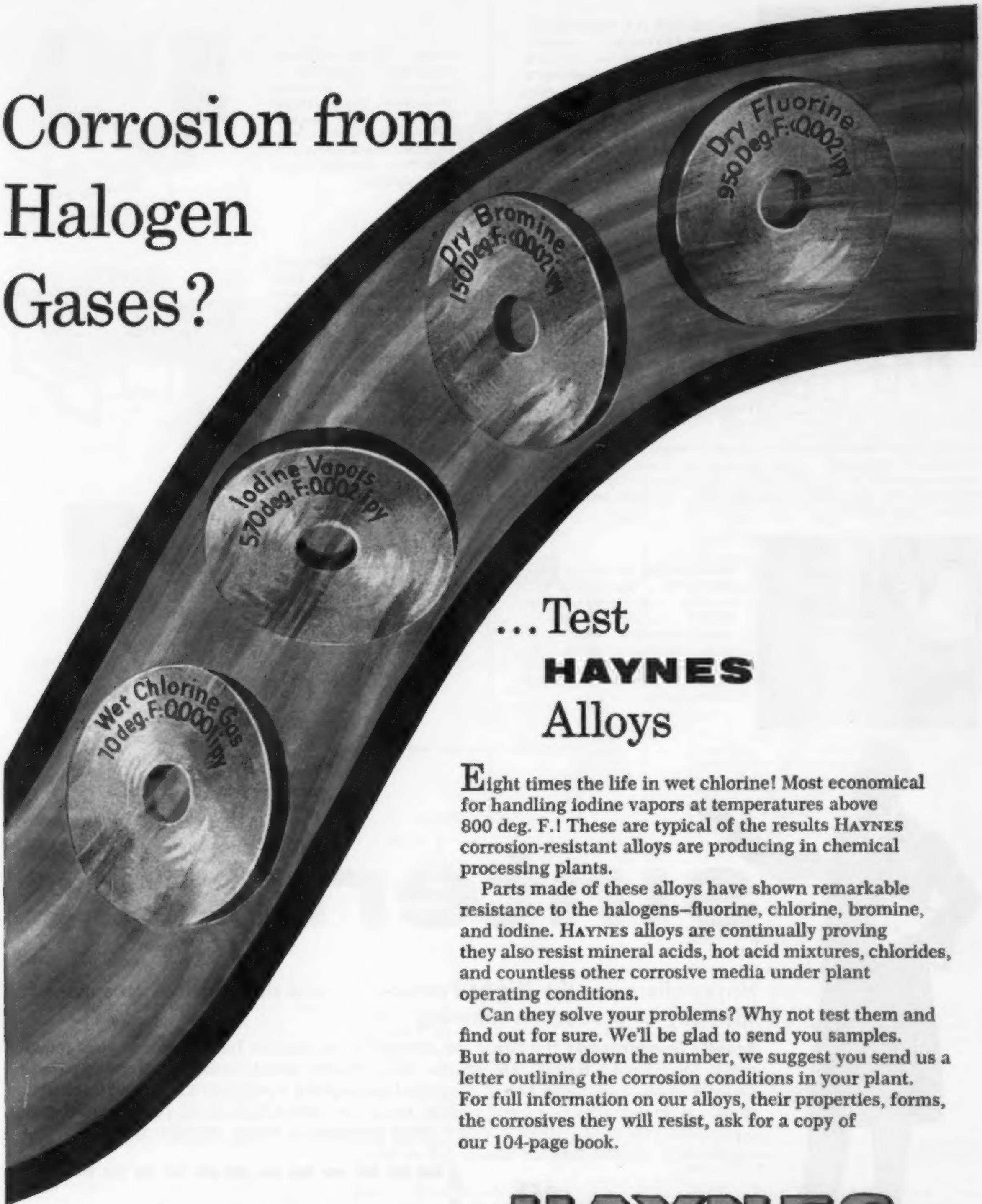

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Circle 1761 on Page 48-A

NEW LITERATURE

Ferrous Metals

1476. Cold Finished Bars
New folder has been issued by *Bliss & Laughlin* detailing the advantages realized in production of parts from bars of superior "Lusterized Finish."

1477. Nickel Alloy Steels
Buyers guide (28-p. booklet) lists steel service centers and their normal stocks. *International Nickel Co.*

1478. Round Edge Steel
Its advantages in production of steel products, its sizes and finishes available from *Caine Steel Co.* set forth in 10-p. booklet.

1479. Steel Bars
Complete story about "Fatigue-Proof" steel bars told in 24-p. booklet—bars "warm drawn". *La Salle Steel Co.*

1480. Strong Stainless
Technical booklet "AM 350 and AM 355" gives the properties and fabrication behavior of these two precipitation hardening stainless steels serviceable to 1000° F. and higher. *Allegheny Ludlum*

1481. Columbium
Information available from *Vanadium Corp. of America* on ferro columbium (both regular ferro alloy and exothermic) with specially high Cb.

Nonferrous Metals

1482. Aluminum Bronzes
20-p. bulletin by *Ampco Metal* gives properties of nine grades having good resistance to wear, abrasion, fatigue, and corrosion.

1483. Indium
Bulletin HP-100 presents facts about three commercial grades of high-purity indium ingot, and applications of the metal, principally for bearings, electrical uses and fusible alloys. *High Purity Metals, Inc.*

1484. Hi-Tensile Al Alloy
March-April number of "Lavingot News and Views" reports on properties and foundry practices of five varieties of ZC81 A and B giving minimum strength of 30,000 psi. *R. Lavin & Sons, Inc.*

1485. Hollow Al Bars
8-p. brochure lists sizes, tolerances, and mechanical properties of hollow Al bars, round or hex. up to 4 in. O.D. and ½-in. wall made by *Harvey Aluminum.*

1486. Magnesium
Brooks & Perkins publishes a quarterly "Magazine of Magnesium" which also considers applications and fabrications of Al, Ti and Boral (a uniform dispersion of boron carbide in Al).

1487. Molybdenum
Looseleaf specifications for mill products in unalloyed Mo and in 0.5% Ti alloy (billets, bars, plates and sheets) give analyses, properties, dimensions and finishes. *Universal-Cyclops Steel Corp.*

1475. Modern Heat Treatment

Bulletin 591, 20-p. in color, illustrates and briefly describes 14 varieties of modern heat treating furnaces especially designed for low-cost, high-production heat treatment of steel and non-ferrous strip, wire, rod, tube and other

mill shapes, and the heat treatment of quality parts in controlled atmosphere. Most of them have associated equipment for quenching or cooling at a regulated rate. *The Electric Furnace Co.*

1488. Self-Aging Al Alloy
Bulletin 103 by *Federated Metals Div. of A.S.&R. Co.* describes "Tenzaloy," a self-aging Al alloy with good casting properties and finishing qualities.

1489. Manganese
Electro-Manganese, metal free of carbon, silicon, or other impurities undesireable for deep-drawing steel sheet, presented in Bulletin 201 by *Foote Mineral Co.*

1490. Rare Earth Metals
Bulletin "Rare Earth and Yttrium Metals" gives forms available, costs, and uses as scavengers and strengtheners. *Lindsay Chemical Div. of American Potash Corp.*

1491. Vacuum Metals
48-p. booklet presents complete view of equipment for making high alloys. *Haynes Stellite Co.*

1492. Ni-Plated Mo
Information from *Fansteel Metallurgical Corp.* Ni improves solderability and workability without large electrical resistance or cost.

Heat & Corrosion Resistant Materials

1493. WI-52
Properties of "Superalloy for Space-Age Castings" made by *WaiMet Alloys Co.* given in Brochure 362-T—especially stress-rupture tests at 1700 and 1800° F.

1494. Stainless Analyses
Tabbed cardboard 8½ x 11-in. filing chart showing analyses of 58 types available from *Peter A. Frasse & Co.*

1495. Porous Stainless Sheet
Release M-208A from *Micro Metallic* Div. of Pall Corp. describes method of making thin sheet of controlled porosity and its utilization in filters of various design.

1496. Thermostat Metal
Data sheet TRU-11 shows various assemblies of multiple elements and methods of determining deflection and force. *Metals & Controls Corp.*

1497. W-545
Vacuum melted, high-temperature alloy described in *Westinghouse's* Technical Data 52-263. It is a complex precipitation-hardening iron-base alloy with high creep resistance up to 1350° F.

1498. Ceramic Coatings
"Rokide Coatings" is the name of a booklet issued by *Norton Co.* giving full details of spray process of protecting metal with Zr, Al, or Cr oxide, Zr silicate or Mg aluminate.

1499. Rene 41
Cannon-Muskegon Corp.'s Technical Bulletin 86 gives high-temperature properties of 36 x 96-in. sheets, 0.015 to 0.125 in. thick, and foil and wire down to 0.001 in.

1500. Refractory Castables
Bulletin R-35A gives information on castable refractories especially resistant to atmospheres high in CO or H. *Babcock & Wilcox Co.*

Tool Materials

1501. Saw Blades
36-p. sawblade handbook and catalogue also discusses cutting problems frequently encountered. *Ladish Co.*

1502. Wire Cutting Machine
Details available from *Mettler Machine Tool, Inc.* about high-speed "unitized" wire straightening and cutting machines handling stock up to 0.18 diameter.

1503. Multiple-Die Press
Information available from *E. W. Bliss Co.* about Model 660 D and 6100 B presses which form as many as ten items per stroke of sheet metal.

1504. Mo-Base Lubricant
Named "Poxylube". Brochure by *Poly Chem, Inc.*, explains applications of two basic formulations (air drying and thermosetting) for metal surfaces.

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Form	Powder
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Odor	Odorless
Specific Gravity	2.91
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Solubility in water in presence of trace amount of $CrCl_2$ or other reducing agent	Very soluble

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Circle 1767 on Page 48-A

1505. Uncoilers
Strip coils up to 6 in. wide and 40 in. dia. can be fed into forming machinery automatically, the power being furnished by the natural "spring" of the uncoiling stock. Literature from *Durant Tool Co.*

1506. Abrasive Tumbling
Information about round and triangular pins called "Tumblex" which finish hard-to-reach areas or grooves in tumbling equipment available from *Norton Co.*

1507. Metal Forming
16-p. booklet catalogs three new high speed forming machines holding all the advantages of radial draw, stretch and compression forming. *Cyril Bath Co.*

1508. Cut-off Wheels
Data available on line of cut-off wheels up to 26 in. dia. made of bonded Al_2O_3 or SiC in various grain sizes and combinations from *Simonds Worden White Co.*

1509. Die Steel
Technical data sheet tells how to handle *Latrobe Steel Co.'s* new BR-3 die steel (2.8% C, 5.2% Cr, 4.5% V) for cold working dies.

1510. Solid Lubricant
4-p. bulletin gives advantages of Alpha Molykote for preventing galling, seizing and metal pickup under high pressure and temperature. *Alpha-Molykote Corp.*

1511. Bending Machines
16-p. catalog shows machines of capacity up to 16-in. pipe, 8-in. angles or 15 x 1½-in. bars wherein dies are moved by hydraulic or pneumatic rams. *Wallace Supplies Mfg. Co.*

1512. Home-Study Course
Information on 15-lesson course "Principles of Machining," for home or in-plant training, from *Metals Engineering Institute.*

1513. Cut-Off Saw
Catalog C-85 presents line of "Marvel" saws and blades with attachments for rapid and economical operation. *Armstrong-Blum Mfg. Co.*

1514. Graphite Dispersions
Acheson Colloids Co. has issued Bulletin 426 explaining the various uses in the metal working field—especially "Prodag" for spray lubricating dies for forging brass and bronze.

Industrial Heating Equipment

1515. Pyrometer Accessories
Thermocouples, protection tubes, insulators, mounts, extension wires and other accessories described in *Bristol Co.'s* catalog.

1516. Vacuum Sintering
Bulletin 4510 explains details of a sintering furnace operating at temperatures up to 4000° F. and pressures down to 0.01 micron. *Kinney Vacuum Division of New York Air Brake Co.*

1517. Quenching Systems
Combined catalog and selection manual for quenching oil coolers. Completely self-contained units with motors, strainers and all controls. *Bell & Gossett Co.*

1518. Vacuum Furnaces
Economical heat treating in a vacuum demands furnaces adapted to the material, size of part, and production requirements. These are discussed in Bulletins 5709 A and B by *C. I. Hayes, Inc.*

1519. Oil Burner
Vortex burner which produces a short intense flame even on residual fuel oil is detailed in Bulletin III by *Thermal Research & Engineering Corp.*

1520. Gas Furnaces
New catalog of entire line of equipment and accessories now available from *American Gas Furnace Co.*

1521. Billet Heaters
Continuous conveyor type of furnaces for heating 2500 lb. of aluminum billets to 1000° F. per hr. presented in Bulletin HT-53. *The Carl Mayer Corp.*

1522. Self-Contained Oven
Data sheet on stainless steel oven to operate up to 660° F. Calibrated thermostat prevents overheating of circulating atmosphere beyond set point. *The Electric Hotpack Co.*

1523. Atmosphere Analysis
"Dewpointer Bulletin" available from *Illinois Testing Laboratories, Inc,* explaining advantages of portable equipment for sampling and analyzing atmosphere existing in any specific zone in a continuous furnace.

1524. Controlled Quenching
Bell & Gossett Co. has issued Catalog FR-853-A of the above title describing portable tanks complete with circulating devices, and "Perambulator" oil coolers.

1525. Induction Heating
An 8-p. booklet by *Ajax Magnethermic Corp.* briefly discusses billet heating, heat treatment, brazing, melting and sintering and requirements of the equipment for the respective operations.

1526. Heat Treating Units
Advantages of heat treating equipment made of sheet alloy—radiant tubes, retorts, boxes, fixtures—presented in booklet by *The Pressed Steel Co.*

1527. Induction Heaters
Literature is available explaining the advantages of "TOCCOtron Radio Frequency" induction heating equipment. Power in various units from 5 to 60 kw. *The Ohio Crankshaft Co.*

1528. Tubular Element Furnaces
Harper Electric Furnace Corp. has issued bulletins describing line of modernized furnaces using "Globar" tubular elements and operating up to 3000° F., and graphite elements, operating up to 5000° F. Heating chambers are 2 in. inside diameter and up to 36 in. long.

1529. 5000° F. Furnace
"Pereco" tube furnace, heated by carbon-resistors described in bulletin by *Pereny Equipment Co., Inc.*

1530. Pit-Type Vacuum Furnaces
Furnaces enclosing pressing dies for compacting billets under vacuum or controlled atmosphere and operating as high as 2000° F., illustrated in Bulletin 557 by *Hevi-Duty Electric Co.*

1531. Dewpoint Control
"Dewtronik" and "Carbotronik" equipment for regulating the carbon potential of furnace atmospheres are described in Bulletin DC-58 by *Ipsen Industries.*

1532. Gas Burners
Catalog sheet, detailing facts about "Buzzer" series of improved and simplified venturi burners with capacity ranging from 200,000 to 1,000,000 Btu. per hr. available from *Charles A. Hones, Inc.*

1533. Nonferrous Treatment
Vol. II, No. 1, of "Heat Treat Review", published by *Surface Combustion* is largely occupied by an article on equipment and methods for heat treating nonferrous metals in prepared atmosphere.

1534. High-Temp. Furnaces
Operating and design data available from *C. I. Hayes, Inc.,* on type M-Y furnace with Mo windings, atmosphere locks and feeding mechanisms. Can be run up to 3300° F.

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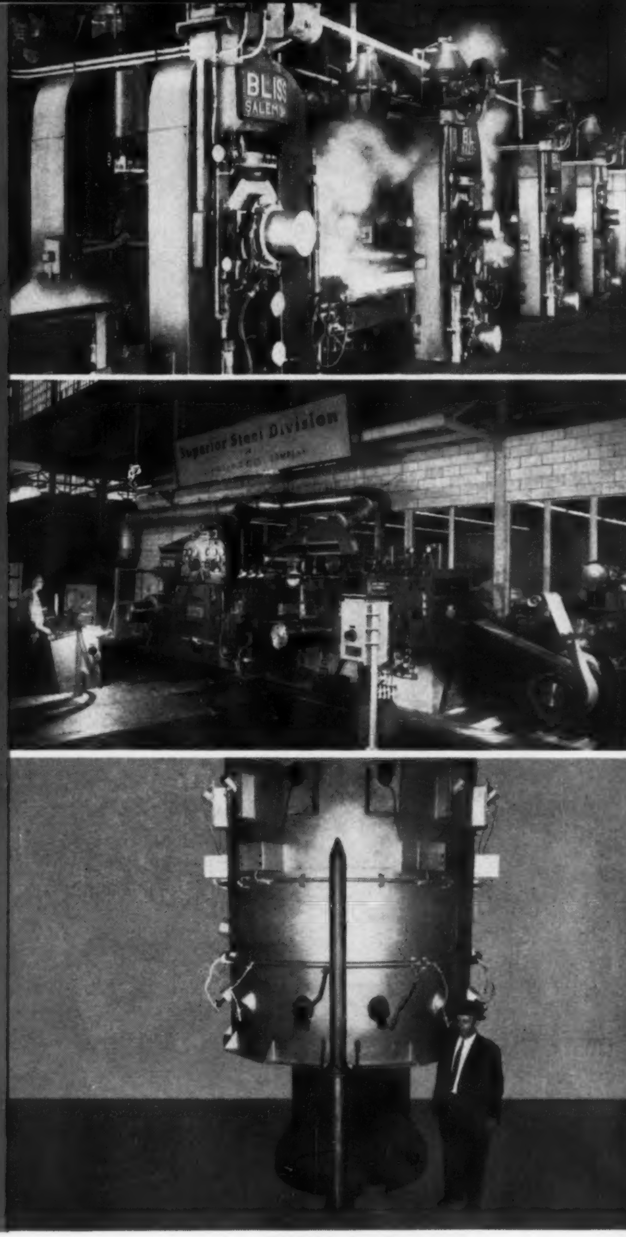

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Circle 1765 on Page 48-A

1535. Bright Annealing of Stainless
As performed at Trent Tube Co. is the topic discussed in the current issue (Vol. 19, No. 1) of "Metal Minutes", published by *Sunbeam Equipment Corp.*

1536. Diffusion Furnaces
Twelve styles of tube furnaces, self contained in unit cabinets, operating up to 2500° F., with uniformity of plus or minus 10° at central portion presented in Bulletin 1081 by *Lindberg Engineering Co.*

1537. Gas-Fired Furnaces
Ajax Electric Co., through acquisition of Barkling Fuel Engineering Co., now offers fuel fired, custom-built furnaces from small to large. Catalog 106A.

1538. Thermocouple Connectors
Foolproof plugs and jacks for connecting thermocouples to extension wires described in Specification FS 005-3 by *Minneapolis-Honeywell Regulator Co.*

1539. Visual Indicators
Wall placard shows relation of visible colors to temperature (eye pyrometry) and gives temperatures indicated by the numerous Tempilstiks, *Tempil* Pellets and Tempilag.

1540. Heat Treating Oven
Details on 5000-lb. capacity, top-loading oven for continuous operation up to 950° F. available from *Young Brothers Co.* Gas fired or electrically heated models.

1541. Atmosphere Control
Folder N-91-620 shows how *Leeds & Northrup's* infrared analyzer equipment regulates gas analysis of generator and various zones in a heat treating furnace.

1542. Long-Lived Trays
Reprint of technical report "The Mechanism of Thermal Fatigue" and its relation to the life of heat treating grids, trays and fixtures is available from *Electro-Alloys.*

1543. Quench Cooler
"Aero" heat exchangers, for cooling quenching baths, a closed system free from dirt and scale, described in Bulletins 120, 124 and 132 by *Niagara Blower Co.*

1544. O-Free Nitrogen
"Nitroneal" generator produces pure nitrogen from ammonia with any desired hydrogen from 0.5 to 25%. Specifications and catalog from *Chemical Div.*

1545. Blowers
Catalog 126 C lists and gives details of complete line of compact blowers with bearings outside of casing. *Spencer Turbine Co.*

1546. Travelling Furnace
Bulletin 653 tells about a double-ended travelling box furnace doing the duty of bell-type bright annealer in a building with low head room. *Hevi-Duty Electric Co.*

1547. Tool Furnaces
Engineering bulletin available from *Waltz Furnace Co.* on complete set-up for heat treating small tools, including preheat, high-heat and quench unit.

1548. Long Mesh-Belt Furnace
With either ribbon or SiC resistors, heavily insulated, for brazing, sintering or bright annealing. *General Electric*

1549. High-Frequency Heating
Lepel High Frequency Laboratories has issued a new catalog showing typical heating coils, electronic tube generators (1 to 100 kw.) and spark gap converters (2 to 30 kw.).

1550. Belt Hearths
Technical literature available about metal belts of various designs and strengths suitable for travelling hearths in continuous furnaces. *Ashworth Bros.*

1551. Controlled Quench
"Ajax Cataract Quench", which duplicates cooling curve of any TTT program, is presented in Bulletin 700 by *Ajax Electric Co.*

1552. Gas Burners
Catalog shows complete line of venturi-type "Buzzer" burners for heating furnaces and cleaning baths. *Charles A. Hones, Inc.*

Cleaning & Finishing

1553. Finishing Barrel
Small parts are efficiently deburred and cleaned in a little hexagonal tumbler so light a man can lift it out of its bearings and carry its contents to an unloading station. Bulletin S-90 on "Handee Slid-Abrader," *Chicago Wheel & Mfg. Co.*

1554. Cleaning & Burnishing
"Clepo 12-K" is a white dust-free granular compound, water soluble, which simultaneously cleans and burnishes steel, brass or copper parts while tumbling from 5 to 30 min. Information from *Frederick Gumm Chemical Co., Inc.*

1555. Vapor Degreaser
36-p. bulletin explains nature of "Nialk Trichlor" and its application whereby more parts can be cleaned per dollar cost of cleaner. *Hooker Chemical Corp.*

1556. Aluminum Cleaners
Mitchell-Bradford Chemical Co. has issued three descriptive bulletins on *(a)* a non-etching cleaner for aluminum, *(b)* a combined cleaner and etcher and *(c)* a solution to remove smut sometimes left on a cleaned and etched surface.

1557. Barrel Finishing
Barrel finishing of small parts prior to tin electroplating and hot dipping is described in Bulletin TPB-5 by *Tumb-L-Matic*

1558. Resistant Coatings
Data sheet 4.5 from *Wall Colmonoy Corp.* describes "Nicrocoat", a brush-on or dip solution, later fused into the surface at 1850° F., giving a bright, lustrous surface similar to Inconel.

1559. Finishes on Silver
Data sheet shows, step-by-step, how to produce various finishes (such as matte, dull satin, butler, and semi-mirror) on solid silver and high-Ag alloys. *Lea Mfg Co.*

1560. Ultrasonic Cleaning
Flyers and folders available from *Industrial Ultrasonics Corp.* showing applications, suggestions for rating various systems, and a system for self regulation called "Auto-Tune".

1561. Degreaser
4-p. folder describes "Vibra-Degreaser" wherein small parts on a vibrating spiral elevator pass through solvent, rinse, vapor cleaner and dryer to unloading chute. *Manpro Corp.*

1562. Steam Jet Cleaner
Described in Bulletin MHYD from *Pan-Tex Mfg. Corp.* Portable and self contained it plugs into 3-phase plant circuit and provides steam for a gun cleaner (with or without detergents) or high-pressure hot or cold water.

1563. Cleaning Concentrate
Loose-leaf bulletin No. 100 describes four compounds formulated to prevent staining of metallic alloy parts while in process without interfering with subsequent finishing or coloring. *Rust-Lick, Inc.*

1564. Infrared Ovens
20-p. bulletin RHC-959 gives complete information about operations, advantages, applications and standardized oven units. *Fostoria Corp.*

Circle 1763 on Page 48-A

1565. Selective Plating
Bulletin DM 201 gives specifications for several assemblages of anodes, solutions and accessories for repairing electroplates and selective electroplating of a wide variety of metals and alloys. *Marlane Development Co.*

1566. Vibrator-Basket
Data available from *Circo Ultrasonic Corp.* on stainless steel basket, on bottom of which is a sealed-in ultrasonic vibrator, useful in degreasers, or operations prior to plating.

1567. Rust Inhibitor
Bulletin 540A by *Prufcoat Laboratories* presents "Prufcoat Primastic," especially recommended as a one-coat protector against marine exposure of all irons and steels, either bare, galvanized or tinned.

1568. Solution Additive
Data Sheet No. 549 (9 pages) describes gluconate additive to caustic soda etching solutions which prevents rock-like accretions of hydrated alumina on tank and coils. *Chas. Pfizer & Co.*

1569. Rust Preventive
Information available from *American Solder & Flux Co.* about "Drygalv," a suspension of Zn powder that can be brushed or sprayed on steel and dries rapidly in a tough film.

1570 Vacuum Metallizing
48-p. booklet explains metallizing (usually by Al) in a vacuum chamber and discusses various base, top and back-up coatings. *Bee Chemical Co.*

1571. Chromate Conversion Coatings
Including chemicals for clear coatings and brighteners, are reported in detail in booklet "Process Chemicals" by *Allied Research Products, Inc.*

1572. Under-Paint Protection
"Cryscoat" iron phosphate in 3-stage wash gives superior tough bond, steel to paint. Bulletin F-9475, *Oakite Products*

1573. Trichlorethylene
Bulletin 44-A presents 36 p. of information on basic degreasing cycles and a new grade ("Nialk") which can be used for flushing and for cleaning. *Hooker Chemical Corp.*

Welding and Joining Equipment and Supplies

1574. Portable Welders
National Cylinder Gas has issued Brochure NH-179 on four different "Sureweld" units, driven by gasoline engines, for either d.c. or a.c.-d.c. welding current. Other literature describes Series SGW-201 units designed for general maintenance and repairs.

1575. Sheet Welder
Hobart Bros. Co. presents a "Micro-Wire Welding" unit which feeds electrode material less than 0.045 in. dia. into an air-cooled CO_2 welding head.

1576. Solder
Flyer gives softening and melting temperatures of 30 commercial solders available in acid core, rosin core, solid wire or sheet. *Anchor Metal Co.*

1577. Head Protectors
28-p. Catalog 36 by *Sellstrom Mfg. Co.* lists complete line of goggles, helmets, face shields and respirators.

1578. D.C. Welder
Complete specifications on model CP-3-VS welder which continuously adjusts voltage while operating and is especially suitable for "X-ray perfect MIG welds in very thin sheet" available from *Miller Electric Mfg. Co.*

1579. Portable Spot Welders
Weighs 24 lb. and is merely plugged into 115-v. a.c. source, and can be handled and operated with one hand, leaving the other free to adjust the work. *Metal & Thermit Corp.*

1580. Resistance Welders
32 special machines, some of them containing up to 74 welding guns, for rapid production of things like refrigerator cabinets, automobile frames, motor shells, window sash, illustrated in Bulletin 8-413 by *Taylor-Winfield Corp.*

1581. Electrodes
Seven data sheets cover as many "Sureweld" a.c. and d.c. electrodes by *National Cylinder Gas* suitable for steel in various carbons, low to high.

1582. Silver Brazing
Bulletin 20, on silver brazing, includes details about alloys, heating methods, joint design and production techniques. *Handy & Harman*

1583. TIG Welder
Specifications for Model BWC-300 MAP welder which removes the d.c. component and balances the wave through the complete operation from start to end available from *Miller Electric Mfg. Co.*

Inspection & Control Equipment & Supplies

1584. Sheet Metal Tester
In a new "TZB" machine for measuring ductility (drawability) of sheet metal by "cupping" test the punch is forced against the sample by a motorized hydraulic pump. Data from *Adolph I. Buehler, Inc.*

1585. Spectrographs
Publication entitled "Introduction to Optical Emission Spectrochemical Instruments" available from *Baird-Atomic, Inc.*

1586. Indentation Testers
Full line of equipment and accessories for hardness testing, manual, power and automatic, set forth in Catalog RT-58 by *Wilson Mechanical Instrument Division*

1587. Microscopes
Catalog describes complete line of metallurgical microscopes, camera attachments, micrometers, vacuum heating stages. *Unitron Instrument Division*

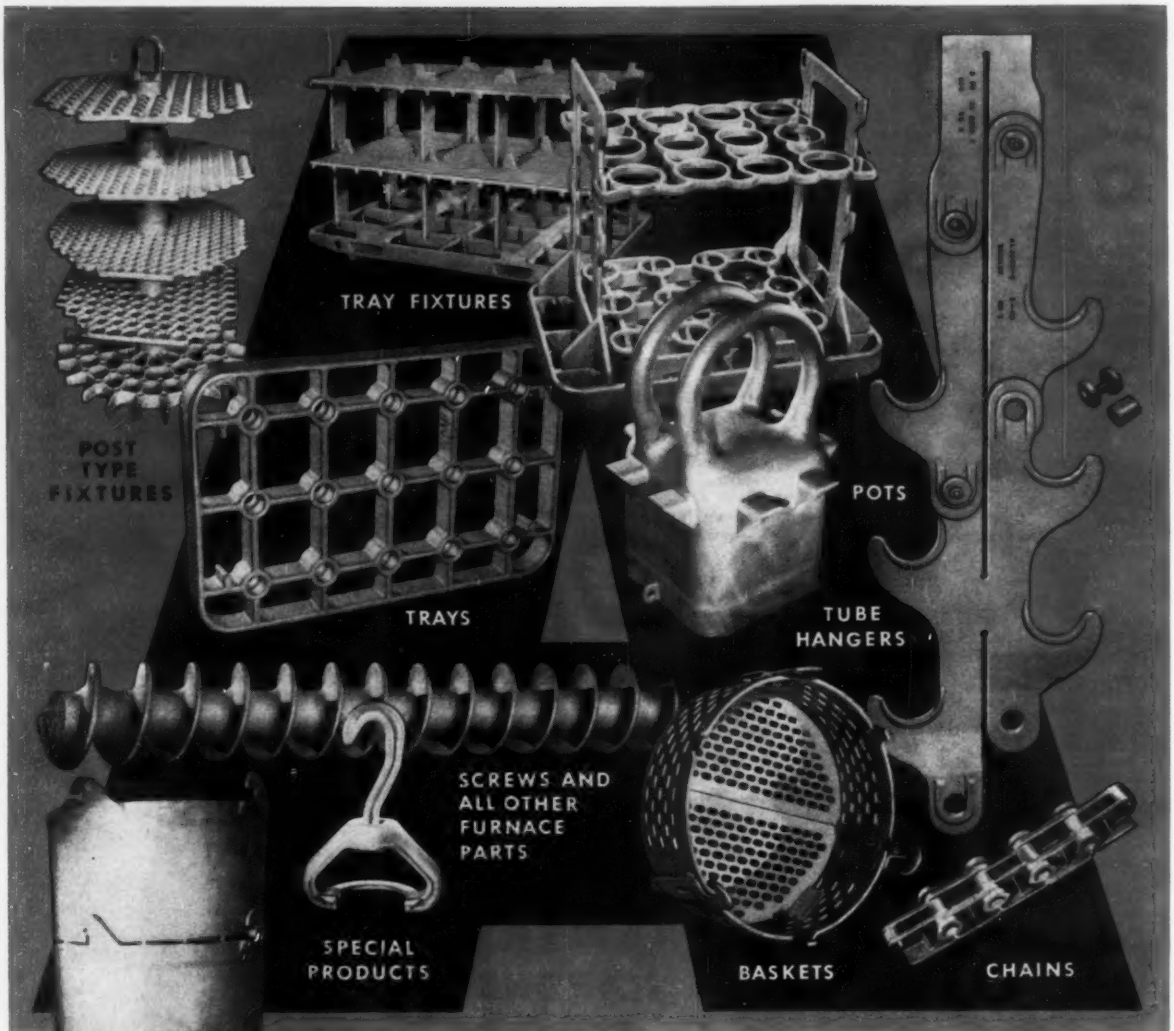
1588. Testing Machine
Full information available on "Electomatic" testing machine with automatic program controller, strip chart recorder and eight testing ranges down to 0.5% of capacity. *Tinius Olsen Testing Machine Co.*

1589. Signalling Controller
Catalog 51 from *Thermo Electric Co., Inc.*, describes a controller assembly in a slide-out chassis taking only 56 sq. in. of space on a panel. Red and green signal lights.

1590. Small Box Furnace
Quick run-up to working temperature (2000°F. max.) and automatic prevention of overshoot is feature of "Stabil-Glow" furnaces. Details of construction available from *Blue M Electric Co.*

1591. Air Gages
The Sheffield Corp.'s 48-p. handbook on "Precision-aire Gaging" lists the tooling and gaging fixtures available and their use with column-type indicators and recorders. (In general the clearance between gage and measured part is measured by amount of air that leaks past.)

1592. Thread Gaging
A comprehensive catalog with the above



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ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

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title has been issued by *Johnson Gage Co.* It includes sections on proper gaging procedure, on detecting wear, and other technical matters.

1593. Testing Machine
Bulletin RF-10-59 concerns "Riehle-Los" machine for imposing fluctuating axial loads at 5 to 1000 cycles per min. Capacities range from 12,000 to 300,000 lb. *Riehle Testing Machines*

1594. High-Temperature Furnace
Data available on small furnace in five sizes with exposed heating elements along walls and door. Controlled temperatures from 300 to 2300° F. and circulating fan to operate up to 1875° F. *L & L Mfg. Co.*

1595. Air Conditioning System
16-p. brochure K-160 describes improved "Kathabar" system whereby air-drying solutions are continuously regenerated. *Surface Combustion*

1596. Test-Piece Heater
W. C. Dillon & Co. has information on a heating cabinet readily mounted to surround test pieces in universal testing machines.

1597. Pressure Transducer
Leaflet 1626 from *Consolidated Electrodynamics Corp.* describes type 4-327, a small transducer insensitive to temperature (−300 to +300°F.) and vibration, with range up to 5000 psi.

1598. Remote Indicator
Specifications available from *Hays Corp.* about a variety of equipment for registering pressure, draft, flow, temperature and liquid level at a distant point.

1599. Plating Gage
Flyer presents "Plategage," self-contained battery-operated unit where two-pronged probe registers thickness of electroplate, paint, enamel or other nonmetallic coating on a magnetic metal. *Dyna-Empire, Inc.*

1600. Hole Gages
Small folder on "Mike" hole gages, made by *Lufkin Rule Co.*, describes probe with expanding contactors which measures directly to 0.0001 in. at bottoms of holes 6 in. deep.

1601. Photo-Electric Micrometer
Has detector which registers the null point on a separate dial and then reads graduations from 0.0001 to 0.0015 in. Details from *Engis Equipment Co.*

1602. Impact Machine
It makes Izod, Charpy or tensile impact tests. Vee-shaped frame gives room for devices for heating or cooling the sample. Motorized hammer hoist, automatic check of swing back permits remote control. Brochure 561; *Testing Machines, Inc.*

1603. Spectro-Photometer
Specifications available from *Baird-Atomic, Inc.*, on infra-red, double-beam machine and attachments with full range of wave lengths from 0.2 to 38 microns and able to scan the 2 to 16 microns range in 4 min.

1604. Environmental Cabinet
Has 19-in. cubical chamber, operates from −120 to +300° F. "Add-on" units adapt it for pressure, vacuum and humidity testing. *Hudson Bay Div. of Labline, Inc.*

1605. Polarizing Microscope
"Polarstar series 2300" presented in 10-p. brochure by *American Optical Co.* It features a fixed polarizer and either a fixed, swing-in or rotatable analyzer and valuable optical and photographic attachments.

1606. Radiography With Ir 190
Budd Co.'s "Gamma Radiography" Bulletin describes "Iriditron" unit, safe to handle on the job yet equivalent to a 260-kv. X-ray machine.

1607. Thermocouple Adapter
Bulletin 2A-1 shows how a spring-loaded adapter can convert a bayonet-type thermocouple into one with the desired length of bare sheath. *Thermo Electric Co., Inc.*

1608. Strain Gages
Pamphlet on "Tatnall Metal Film 102" strain gages usable to 400°F., showing configurations (comb, rosette and miniature) available. *The Budd Co.*

1609. Optical Flatness
The "Baker Surface Finish Interference Microscope" is described in an 8-p. booklet by *Cooke, Troughton & Simms*, whereby the quality of the surface can be assessed at a glance.

1610. Testing Machine Accessories
16-p. Bulletin RI-S-59 describes extensometers for tests in vacuum or controlled atmospheres up to 4000° F., dual range extensometers for use at room temperature, and automatic strain rate controllers. *Riehle Testing Machines*

1611. Borescopes
Catalog of equipment for internal inspection, bright view without distortion. *Engelhard Industries*

1612. Stress-Strain Recorder
"XY Electromatic," described in Bulletins 54 and 59, records strain in inches per inch. Scales and ranges changed by flip of a switch. *Tinius Olsen Testing Machine Co.*

1613. Metallograph
"Research" type of equipment readily interchanged from bright to dark field, polarized light or phase contrast. Catalog E-240. *Bausch & Lomb Optical Co.*

1614. Thermocouples
Thermocouple wires from 0.020 to 0.50 in. OD, in wide variety of sheathing, described in Bulletin 1200-4 by *Claude S. Gordon Co.*

1615. Sample-Polishing Methods
"The AB Metal Digest" is a bi-monthly booklet published by *Buehler Ltd.*, containing information on all methods of metallographic polishing and equipment therefor.

1616. Radiography
Illustrated booklet of case histories where radiography has raised efficiency in production. *Ansco*

1617. Atmosphere Analyzer
New indicator shows content of O_2, CO, CO_2 and CH_4 in furnace atmosphere, plus four other components as desired. Specifications from *Perkin-Elmer Corp.*

Production & Casting Equipment & Supplies

1618. Die Casting Machine
Information is available on "DCMT MAC 99," an inexpensive single-cycle die caster. Push button starts an automatic cycle. Safety devices, and die block cooler and cleaner are included. *DCMT Sales Corp.*

1619. "Vacuum Reports"
Is the name of a small magazine issued by *Kinney Vacuum Div. of N.Y. Air Brake Co.* The current issue, No. 3, features an article on precision die-cast parts for cameras.

1620. Al Melting Furnace
Information on Model RSHCH melting furnace, especially for Al die-casting machines, designed to minimize H pick-up. *J. A. Kozma Co.*

1621. Dust Catchers
28-p. "Freedom From Dust" gives full

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particulars of six basic designs of filters or collectors for dry dust (up to 600°F.). *Dracco Div. of Fuller Co.*

1623. Sand Rammers

4-p. form 5216A from *Ingersoll-Rand* presents three new "sand wiper" rammers (hand operated) which double the number of blows per minute with the same air consumption.

1624. Graphite

8-p. booklet on metallurgical uses of "Mexican" (natural amorphous) graphite, such as mold wash, refractory facings, innoculant for gray iron and alloying agent, available from *U.S. Graphite Co.*

1625. Leak Detector

Bulletin 1857 is a 4-p. brochure with conversion formulae and other information about mass spectrometers as leak detectors. *Consolidated Electrodynamics*

1626. Coated Sand

"Faskure" is a fast-curing, resin-coated sand for shell molds, available in several standard mixes. Literature available from *Aurora Metal Co.*

1627. Vacuum Gage

Model 751 gage and control with almost zero drift and designed to measure down to 10^{-10} mm. Hg directly is presented in literature by *NRC Equipment Corp.*

1628. Oxygen Steelmaking

Is the subject of No. 241 of "Jalmet Notes" published bi-monthly by *Jones & Laughlin Steel Corp.*

1629. Melting Furnaces

Hevi-Duty Electric Co.'s Bulletin 591 shows 33 types of gas-fired furnaces (pot, crucible, chamber and reverberatory) for all types of nonferrous alloys. Capacities range from 100 to 60,000 lb.

1630. Tube Mills

88-p. "Tube Mill Book" gives complete information on the wide variety of mills for electric welding ferrous or nonferrous tubing from 0.25 to 26 in. dia. *The Yoder Co.*

1631. Induction Melting

Bulletin 70 by *Inductotherm* describes numerous innovations in induction furnace design and operation.

1632. Super Refractories

Is the title of a booklet by *Carborundum* which includes information on resistance to wear, either by fine particles in air blast or by direct sliding of solids.

1633. Fe-Mn-Si

4-p. folder F20093 shows how chromium in stainless-steel slags can be reduced up to 4% by proper use of Fe-Mn-Si. *Union Carbide Metals Co.*

1634. Air Heater

Bulletins 112 and 113 describe direct and indirect-fired heaters for cupola hot blast, recirculating ovens and drying. *Thermal Research & Engineering Corp.*

1635. Vacuum Sintering

Heraeus Induction Sintering Furnaces capable of operating at 5000°F. with coils from 7 to 20 in. dia. described in Bulletin 4-25 by *Consolidated Vacuum Corp.*

Parts, Forms, Shapes

1636. Powder Metals

Metal Powder Producers Assoc. has issued a loose-leaf book giving brief specifications of the metal powders available from each of the 29 firms belonging to the association.

1637. Metallic Mirrors

Fabrite Metals Corp. has literature describing quality and applications for "Ferrotypes," "Press Plates," or mirror-polished plates of spring-temper brass up to 6000 sq. in.

1638. Flat Wire

Technical Data Sheets 502 to 506 give information on ultra-fine flat wire, strip and foil of stainless, magnetic, high-temperature and reactive alloys. *Precision Metals Div. of Hamilton Watch Co.*

1639. Aluminum Extrusions

Folder presents information on equipment available for custom extruding up to 4 in. major dimension. *Aluminum Extrusions, Inc.*

1640. Stainless Tubing

Vol. II of "Metals for Precision and Performance," printed by *J. Bishop & Co.* reprints 11 brief articles about important applications.

1641. Aluminum Screws

A wealth of information about standard and special screw fasteners is given in a 48-p. booklet by *Reynolds Metals Co.*

1642. Iron Powder

Booklet ADV 1028 gives chemistry, physicals and evaluations on "HS 6460," capable of making compacts with 100,000-psi. tensile after heat treatment. *Republic Steel Corp.*

1643. Ni-Clad Cu Wire

Handy reference guide to its properties, advantages and applications. Combines high heat and electrical conductivity of Cu with stability and strength of Ni. *Riverside-Alloy Metal Div.*

1644. Coated Small Wire

Flat, round, square, rectangular, for ready soldering and mass production of small parts described in folder by *Little Falls Alloys, Inc.*

1645. Free-Cutting Cu Alloys

20-p. booklet gives compositions, sizes, tolerances, machinability of leaded brasses, bronzes and nickel-silvers. *Titan Metal Mfg. Co.*

1646. Welding Fittings

Tubular Products Div. of *Babcock & Wilcox Co.* has issued 24 folders FDC 252 to 275 cataloging fittings and flanges for pipe sizes up to 36 in.

1647. Steel Tubing

Bulletin CS 60, "Ostuco Steel Tubing" gives specifications for seamless steel tubing manufactured by *Ohio Seamless & Tube.*

1648. Parts in Al and Mg

Dow Metal Products Co.'s facilities for making castings (sand, permanent or die molded), extrusions, rolled shapes, or complete fabrications presented in 12-p. booklet.

1649. High-Pressure Tubing

Data Memorandum No. 22 by *Superior Tube Co.* presents data on sizes, types, applications and stress formulas for four types of stainless tubing and A.I.S.I. 4130 steel.

1650. Wire Cloth

94-p. catalog contains specifications and information about uses of wire cloth made in nine basic weaves in any commercial metal or alloy wire. *Cambridge Wire Cloth Co.*

1651. Brass Forgings

32-p. "Titan Forging Handbook" argues the proposition that quality, strength and appearance of forgings are superior to sand castings. *Titan Metal Mf. Co.*

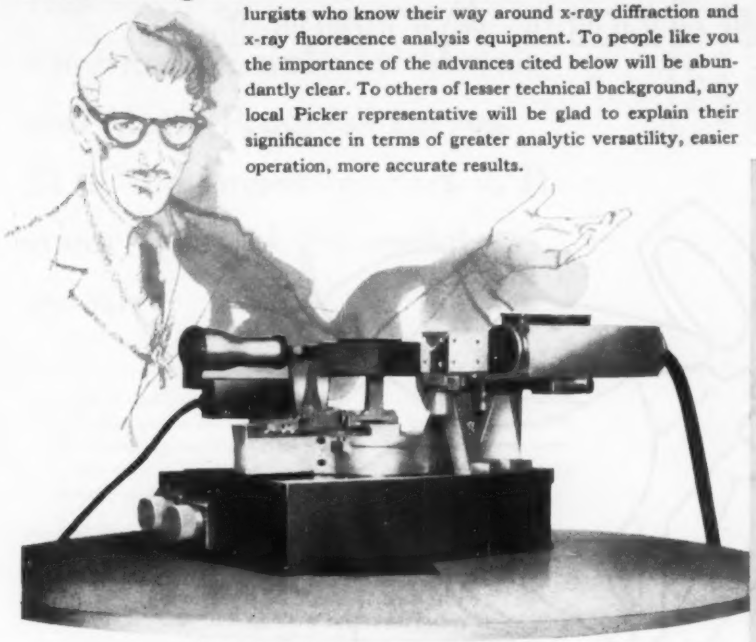
1652. Bimetal

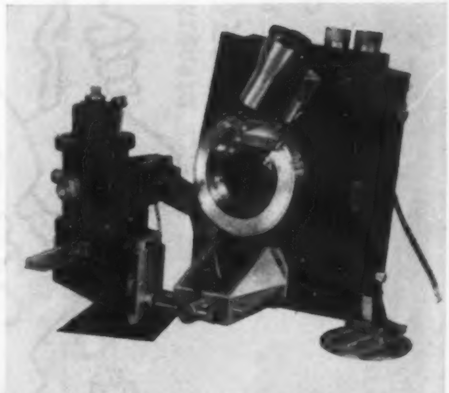
Booklet "Successful Applications of Themostatic Bimetal" available from *W. M. Chace Co.*

1653. Steel Castings

"Sinews of Modern Living" is the title of a 28-p. booklet illustrating 200 representative steel castings in various industries. *Steel Founders' Society of America*

we're talking here to analytical chemists, crystallographers and metallurgists who know their way around x-ray diffraction and x-ray fluorescence analysis equipment. To people like you the importance of the advances cited below will be abundantly clear. To others of lesser technical background, any local Picker representative will be glad to explain their significance in terms of greater analytic versatility, easier operation, more accurate results.





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rotate sample independently about diffractometer axis for special precision-procedures . Makes for jiffy alignment of specimen or analyzer crystal, or detection of preferred orientation

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The American Society for Metals and Metal Progress serves 31,000 member-readers in 11 major areas of the metals industry.

The ASM is the communications center for technical information wherever metals are produced, processed, fabricated, designed, tested and applied. Metal Progress, monthly engineering magazine of the Society, reports on engineering developments in these 11 major technological areas:

FERROUS METALS: Alloy, Carbon, Free Machining, Stainless Steels, Hot and Cold Finished Bars.

NONFERROUS METALS: Aluminum, Beryllium, Brass, Bronze, Columbium, Copper, Lead, Magnesium, Molybdenum, Monel, Nickel, Rare Earths, Tantalum, Titanium, Tungsten, Zinc, Zirconium.

HEAT- AND CORROSION-RESISTANT AND ELECTRICAL MATERIALS: Special Alloys; Carbon, Graphite; Ceramics, Cermets, Thermal Insulating and Special Electrical Materials.

RADIATION AND NUCLEAR MATERIALS & EQUIPMENT: Metallic and Non-Metallic Reactor Materials, Fuel Elements, Pressure Vessels, Control Elements, Related Equipment.

TOOL MATERIALS, CUTTING AND FORMING EQUIPMENT: Abrasives; Carbides; Coolants, Oils and Lubricants; Arc and Gas Cutting Equipment, Saws; Forging, Pressing, Extruding Chemical Milling, Slitting, Straightening and Spinning Equipment; Tool and Die Steels, Plastic and Other Short-Run Die Materials.

INDUSTRIAL HEATING EQUIPMENT AND SUPPLIES: Atmosphere Generators and Gases; Commercial Services; Furnaces; Controls, Indicators and Recorders; Induction, Flame and Salt Bath Equipment; Ovens; Pyrometers; Quenches; Samplers and Analyzers; Trays, Refractory Parts.

CLEANING AND FINISHING EQUIPMENT AND SUPPLIES: Alkaline Cleaning, Pickling, Degreasing, Buffing, Polishing, Blasting, Plating Porcelain Enameling, Purifying, Painting Equipment and Supplies; Rust Preventives; Abrasives.

WELDING AND JOINING EQUIPMENT AND SUPPLIES: Gas, Resistance and Arc Welding Equipment and Supplies; Electrodes; Adhesives, Fasteners; Hard Surfacing, Brazing and Soldering Equipment and Supplies.

INSPECTION AND CONTROL EQUIPMENT AND SUPPLIES: Microscopes and Attachments; Analytical and Mechanical Equipment; Gages, Comparators, Hardness Testers, Nondestructive, Electronic and Other Scientific Inspection Equipment.

PRODUCTION AND CASTING EQUIPMENT AND SUPPLIES: Electric and Vacuum Melting Furnaces; Refractories; Ferro Alloys; Foundry Irons and Coke; Rare Earths; Alloying and Refining Agents; Annealing, Soaking and Sintering Furnaces; Rolling Equipment; Industrial Gases; Foundry Equipment and Supplies.

PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS: Castings (Malleable, Gray Iron, Steel, Non-Ferrous), Forgings, Extrusions, Powder Metal Parts, Springs, Stampings, Tubings, Weldments, Wire.

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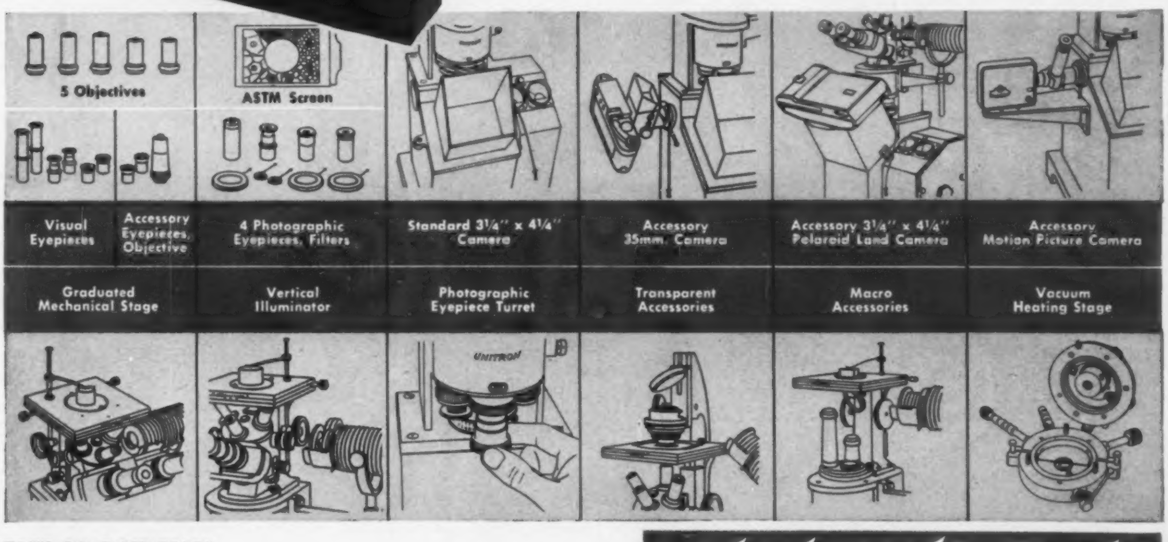
In METALLOGRAPHS...

the trend is to UNITRON!

What do you look for when choosing a metallograph? All of the popular makes are precision instruments, are reasonably versatile and, to a varying degree, are easy to operate. But, except for UNITRON, all have the bulk of an office desk or optical bench and are tagged with a price that puts a substantial dent in the laboratory budget. UNITRON, and only UNITRON, offers a completely equipped metallograph in a compact and self-contained unit, taking only 9" x 12" of table space, which duplicates the performance of large cumbersome instruments — and at a price which is hardly more than the usual cost of a conventional metallurgical microscope.

Unlike the case with most metallographs, an adding machine is not required to compute its cost. Coated optics supplied as standard equipment include 5 objectives, 4 photographic eyepieces and 3 pairs of visual eyepieces. These give a magnification range of 25X-2000X. Also included in the purchase price are the built-in 3¼" x 4¼" camera and viewing screen; high-intensity illuminator for vertical, oblique, and transmitted light; variable transformer with both voltmeter and ammeter; accessories for transparent specimens; polarizing apparatus; filters; film holders; stage clips; cabinets etc. Optional extra accessories include Polaroid Land, 35mm. and movie camera attachments; low power (5X-40X) objectives for macro work; vacuum heating stage for temperatures to 1100°C and long working-distance 40X objective; ASTM Austenite grain size viewing screen and eyepieces; filar micrometer eyepiece; and additional optics.

Such a combination of features, versatility, convenience, and value is indeed unique with UNITRON. Little wonder then, that more and more laboratories are choosing UNITRON . . . from the large organization adding another metallograph to its equipment, to the small company buying an instrument for the first time.



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UNITRON's Metallograph and Universal Camera Microscope Model BU-11 with binocular eyepiece; objectives: M5X, M10X, M40X, 40X for transmitted light, 100X oil immersion; paired visual eyepieces: R5X, Ke10X Micrometer, Ke15X; photo eyepieces: 10X, 15X, 20X, Micrometer; etc., as described above.

$1379
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Monocular Model U-11 **$1195**

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INSTRUMENT DIVISION OF UNITED SCIENTIFIC CO.
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Please rush UNITRON's Microscope Catalog 2-C

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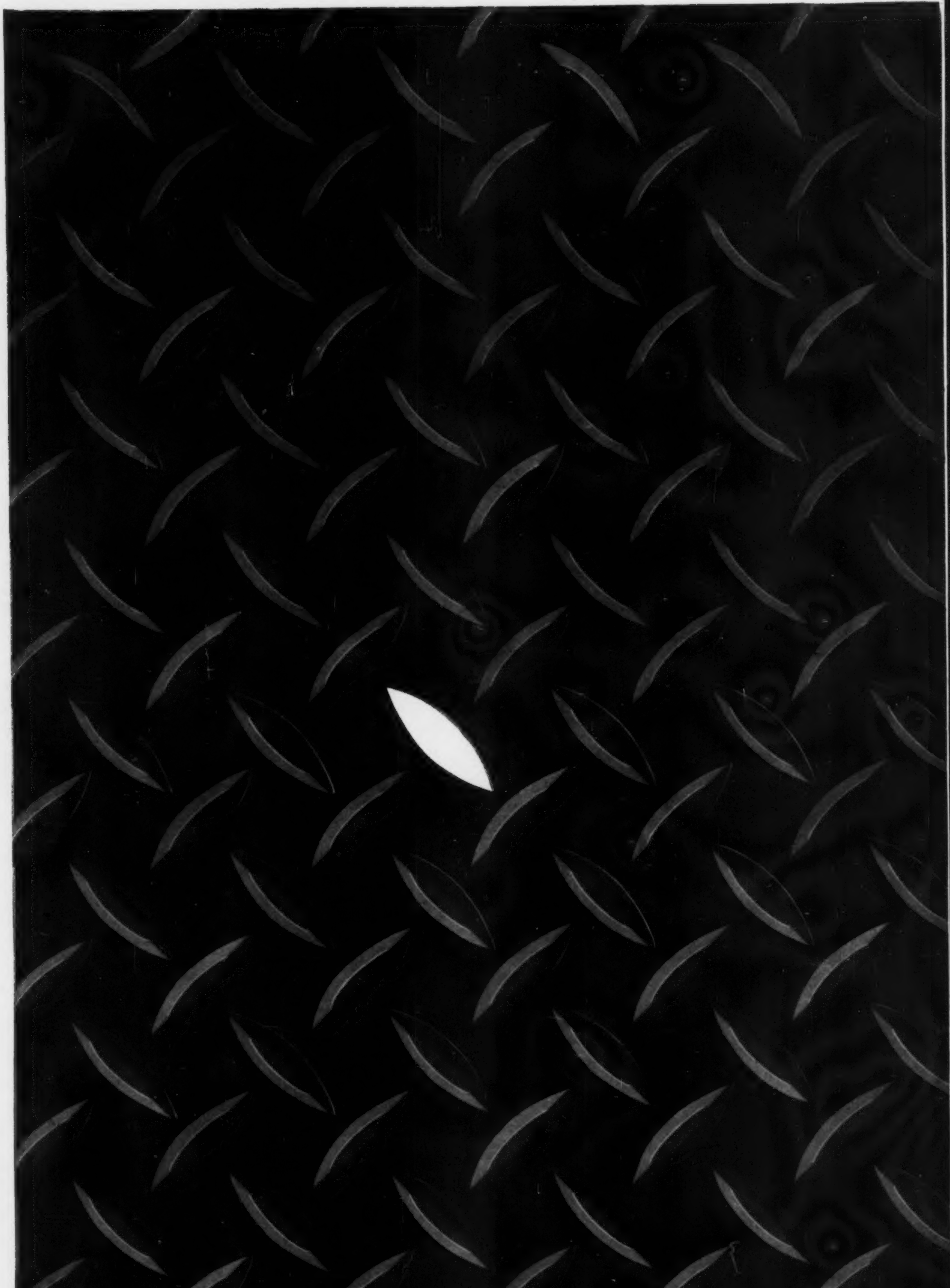
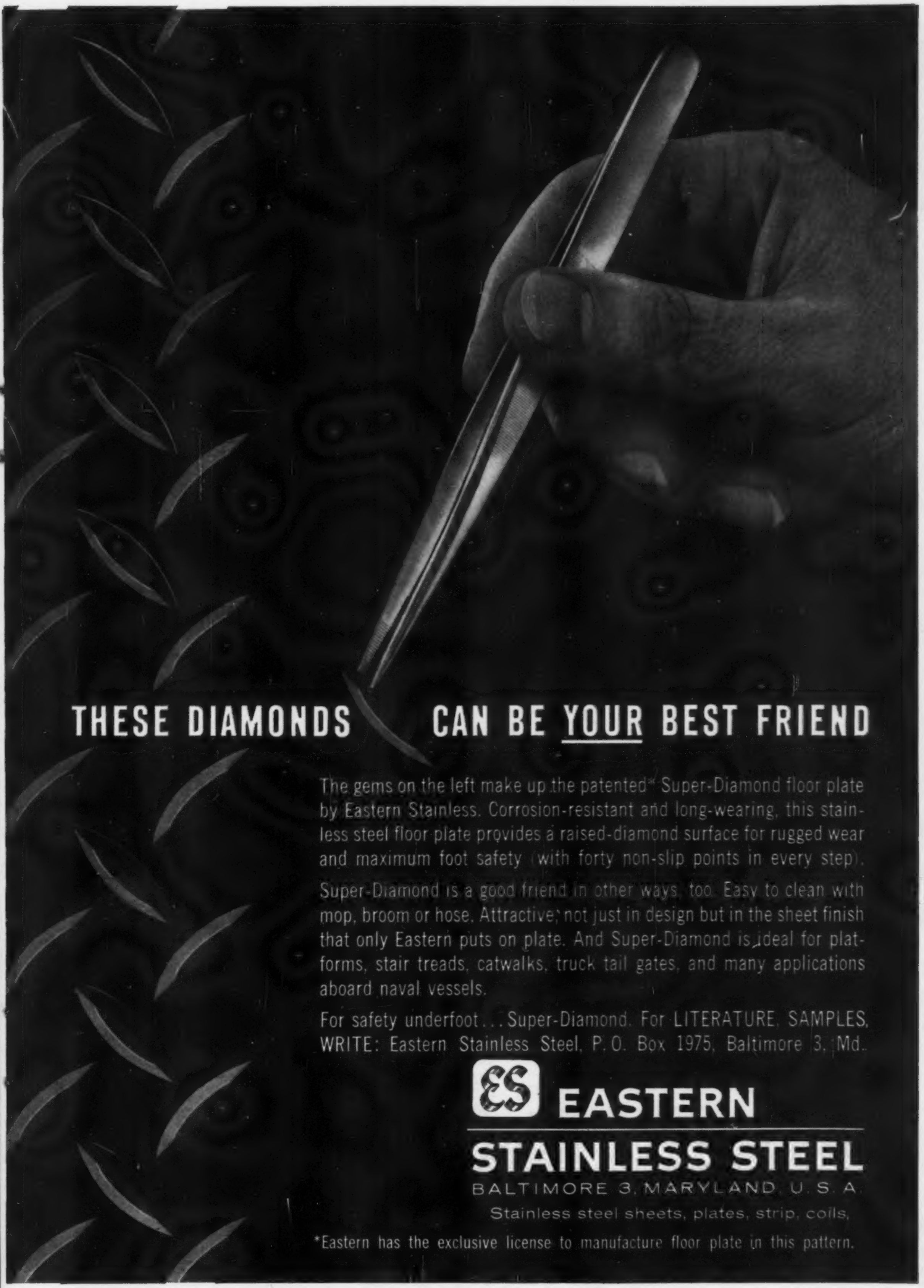
THE TREND IS TO UNITRON

Circle 1654 on Page 48-A




THESE DIAMONDS CAN BE YOUR BEST FRIEND
The gems on the left make up the patented* Super-Diamond floor plate by Eastern Stainless. Corrosion-resistant and long-wearing, this stainless steel floor plate provides a raised-diamond surface for rugged wear and maximum foot safety (with forty non-slip points in every step).
Super-Diamond is a good friend in other ways, too. Easy to clean with mop, broom or hose. Attractive, not just in design but in the sheet finish that only Eastern puts on plate. And Super-Diamond is ideal for platforms, stair treads, catwalks, truck tail gates, and many applications aboard naval vessels.
For safety underfoot . . . Super-Diamond. For LITERATURE, SAMPLES, WRITE: Eastern Stainless Steel, P. O. Box 1975, Baltimore 3, Md.
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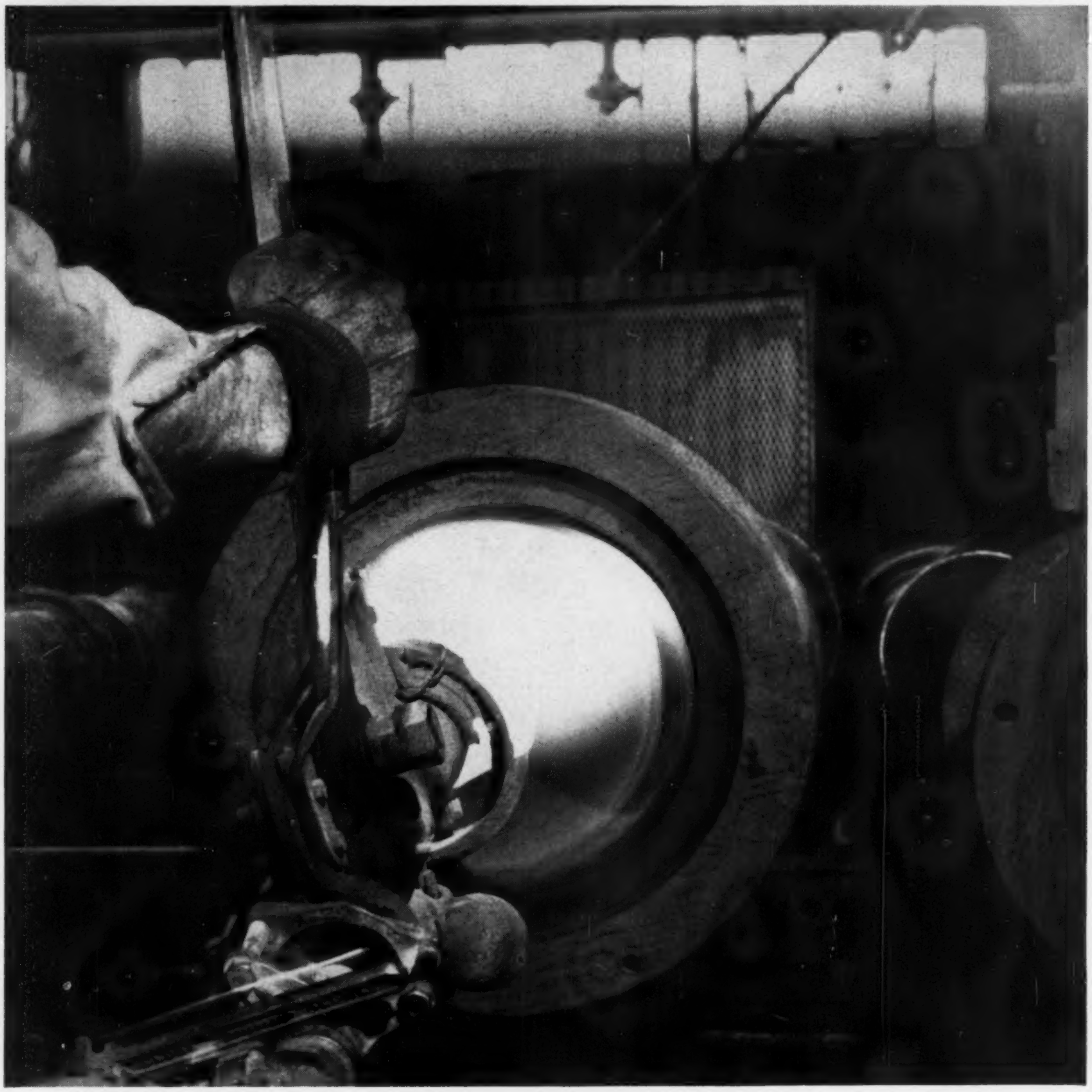
Stainless steel sheets, plates, strip, coils.
*Eastern has the exclusive license to manufacture floor plate in this pattern.

Intense heat from four Gas-fired torches skin dries pipe molds in as little as 2 minutes, after ramming and facing with a blacking material.



Only GAS provides the clean, uniform heat needed to skin dry pipe molds! Millions of BTU's of clean, uniform heat are required every hour by Warren Foundry & Pipe Division of Shahmoon Industries, Inc., Everett, Massachusetts, to skin dry its pipe molds.

Only Gas provides this volume of heat without any problems of shipping and storage. That's why Warren Foundry chose Gas to solve this large scale heating problem. And as plant engineer William Mitchell says, "We chose Gas over other fuels because of its cleanliness and uniformity of heat value."

For information on how Gas can help you with your production problems, call your Gas Company's Industrial Sales Engineer. He'll be glad to discuss with you the economies and outstanding results you get with the clean, uniform heat of Gas, and modern Gas-fired industrial equipment. AMERICAN GAS ASSOCIATION

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Alcoa puts the metal where you want it

How BIG an impact have you seen lately? Alcoa can now make them up to 12 in. in diameter and 60 in. long.

When Alcoa's new 2,500-ton press hits an aluminum alloy slug, a giant impact is formed with the combined strength of an extrusion and forging.

Like their small brothers, these big new impacts can save you money. They are produced in one fast operation. There's no parting line to be ground. No scale to be removed. No draft to be cut off. Impacts have forged bases and extruded sections. Multiple parts can often be combined into one integral impact eliminating welded or mechanical joints. Machining is reduced, and excessive material waste is eliminated.

You can get these big new Alcoa® Impacts in many alloys with tensile strengths up to 75,000 psi. Also made from aluminum powder metallurgy alloys which provide excellent properties at elevated temperatures.

Alcoa Impacts are unfailingly sound. They have smooth, corrosion-resistant surfaces. You can have them in plain or complex shapes with design features combining those of forgings and extrusions—flanges, steps, multiple walls, bosses, ribs.

In impacts, as well as forgings, castings, extrusions and screw machine parts . . . Alcoa puts the metal where you want it. A call to Alcoa can mean ingenious design solutions. Start now; write for *Metal in Motion*, Alcoa's new 34-page brochure on impacts. Aluminum Company of America, 913-E Alcoa Building, Pittsburgh 19, Pa.

ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA

Alcoa puts the metal where you want it . . in impacts, castings, forgings, extrusions and screw machine parts.

Circle 1657 on Page 48-A

Just a little

Vancoram Ferrovanadium does such a big job! Vancoram Ferrovanadium does an outstanding job in a surprisingly economical way! In constructional steels, tool and die steels, deep-drawing steels, cast and forged steels, and in cast irons, no other alloying element is so versatile. It readily forms stable carbides and controls grain growth. In cast irons it is unusually effective in restraining graphitization. Vanadium imparts toughness, durability, strength and resistance to wear. Try it and see!

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Catching Up with a Slippery Equation

What goes on when two moving surfaces are separated by a film of oil?

Simple question? Maybe, but engineers and mathematicians have been trying to answer this classic question of lubrication ever since Osborne Reynolds neatly stated the problem in equation form back in 1886.

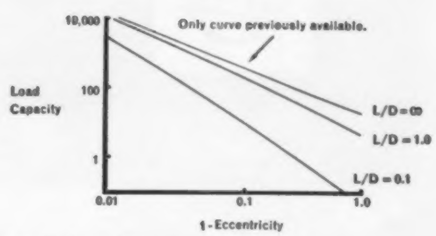
Unfortunately, analytical methods for solving Professor Reynolds' partial differential equation worked only for unrealistic oil bearings, bearings with widths approaching zero or infinity. And approximate methods were crude, requiring a complete recalculation for each slight change in the bearing.

Recently, mathematicians at the General Motors Research Laboratories came up with the most versatile and efficient method of solution yet made. Their analytical method for solving the two-dimensional Reynolds' equation applies to all finite journal bearings — as well as other hydrodynamic bearings — with *no* assumptions or approximations about boundary locations. The new method uses a long-neglected energy theorem recorded by Sir Horace Lamb instead of the force relationship tried by Reynolds and others.

Besides being a valuable contribution to the theory of lubrication, this work has its practical side: namely, accurate, serviceable design curves for engineers. At GM Research, we believe delving into both the theoretical and applied sides of a problem is important to progress. It is a way of research that helps General Motors fulfill its pledge of "more and better things for more people."

General Motors Research Laboratories
Warren, Michigan

Hydrodynamic analyses have led to specific answers about bearing operation. Shown here are the oil pressure distribution (main illustration) and load-carrying capacity for a non-rotating journal with a reciprocating load.



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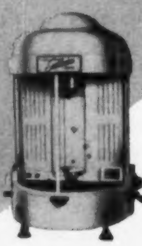
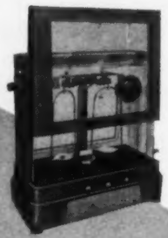
A Balance for every weighing . . . and a Balance that will perform the weighing to the accuracy required in the shortest possible time. Most of our extensive line of domestic and imported balances is illustrated and described in the 32-page Harshaw Scientific Balance Bulletin. Do you have your copy? In addition we will gladly furnish detailed information on particular balances.



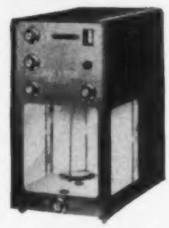
H-2424—Balance, Analytical, Sartorius "Selecta Rapid" model. Capacity—200 grams. Sensitivity—1/10 mg. Single Pan. *No weight handling.* Weights are an integral part of balance and are added by flick of external knobs.

Price **$890.00**



H-1823—Balance, Analytical, Becker Model "AB-2." Two Pan. Dial reading chainomatic, with notched beam. Capacity—200 grams. Sensitivity—1/20 mg.

Price. **$449.00**

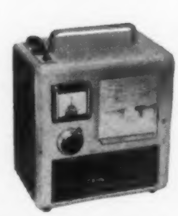


H-1642—Balance, Analytical, Ainsworth "Right-A-Weigh" Type S,C. Capacity—200 grams. Sensitivity—1/10 mg. Single Pan. *No weight handling.* Features substitution weighing.

Price **$895.00**

H-2400—Balance, Analytical, Sartorius "Projecta Rapid" Model. Capacity—200 grams. Sensitivity—1/20 mg. Two pan. *No weight handling up to 10 grams* (weights up to 10 grams are built-in).

Price **$645.00**



H-1905—Electrobalance. Cahn, Range Selector Model. For micro weighings quickly and accurately. Maximum range—0-100 mg. with 25 micrograms sensitivity. Four other ranges down to 0-1 mg. with increased sensitivity.

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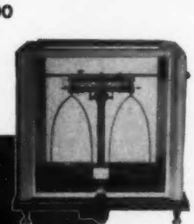
H-2440—Balance, Analytical, Voland Model 100N. Capacity—200 grams. Sensitivity—1/10 mg.

Price **$125.00**



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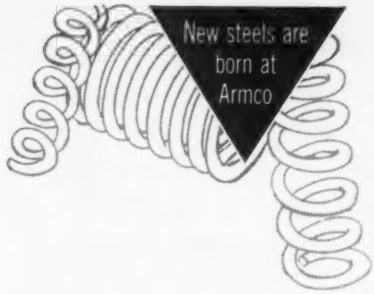

Advantages of 17-7 PH Stainless Steel For Springs in Severe Service

Excellent elastic properties, strength at high temperatures, resistance to corrosion—all are combined in Armco 17-7 PH Stainless Steel wire to make it an outstanding material for springs operating under severe conditions.

Armco 17-7 PH is one of a family of Armco Precipitation-Hardening Stainless Steels developed to meet the exacting needs of space age technology. For springs it offers a unique combination of properties that make it especially useful in applications involving heat or corrosion, where ordinary spring materials don't hold up.

EXCELLENT ELASTIC PROPERTIES

In tension, the elastic limit of 17-7 PH wire is approximately 75% of ultimate tensile strength; in torsion, about 55%. The figures in Table 1 give an idea of the excellence of these values. See table 2 for a comparison with 18-8 stainless and music wire. Relaxation and torsional modulus values of 17-7 PH stainless hold at high levels even at temperatures up to about 650 F.

TABLE 1
Typical Room Temperature Properties of .052 to .061-inch 17-7 PH Wire

CONDITION	PROPERTIES			
	UTS, psi	0.2% Yld. Str., psi	Elong. in 2", %	Fatigue Str. * % of Tens. Str. at 10^7 Cycles
C	250-280,000	230-260,000	—	—
CH 900	305-335,000	285-315,000	2-4	36

*Machined and polished surfaces

TABLE 2
Comparison of Typical Mechanical Properties of Armco 17-7 PH Condition CH 900 Wire, 18-8 Spring Wire and Music Wire

	17-7 PH	18-8	MUSIC WIRE
Diameter, Inches	Ultimate Tensile Strength, 1000 psi		
.030	320-350	280-310	340-365
.093	279-309	230-260	285-305
.148	256-286	201-231	263-280
.192	252-282	185-215	252-267
Diameter, Inches	Max. Torsional Stress When Closed Solid, 1000 psi		
.050	170	113	160
.100	160	100	140
.150	155	93	130
.200	150	87	—

CORROSION RESISTANCE

Armco 17-7 PH Stainless Steel extends the dependability of springs beyond that of metals with comparable strength but inferior resistance to corrosion. In Condition CH 900, for example, the condition most widely used for wire products, 17-7 PH resists corrosion as well as 18-8 full-hard temper stainless steel. Even in a marine atmosphere, 2 years' exposure produces only superficial rusting.

SPRING FABRICATION

Availability of 17-7 PH round or flat wire, coils or straight lengths, and a wide range of sizes and conditions, makes it adaptable to the production of a great many kinds of springs.

It's workable as well. In Conditions C and CH 900, for example, 17-7 PH wire can be wrapped on its own diameter. However, because Condition C is more ductile, it is preferred for spring coiling, especially on automatic machines.

The low-temperature precipitation hardening of 17-7 PH after fabrication takes care of stress relieving too. No further heat treatment is required as with other hardenable spring materials. Thus a production operation is eliminated and the possibility of dimensional changes is avoided. Also, because no heavy scale is produced and because plating is not necessary, 17-7 PH springs are not exposed to hydrogen-absorbing conditions. A very light pickle will remove heat tint.

SEND COUPON FOR DATA

For more information on Armco 17-7 PH Stainless Steel or its special precipitation hardening companion grades, 17-4 PH and PH 15-7 Mo, just fill in and mail the coupon. There's no obligation.

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Circle 1661 on Page 48-A

Kanigen®

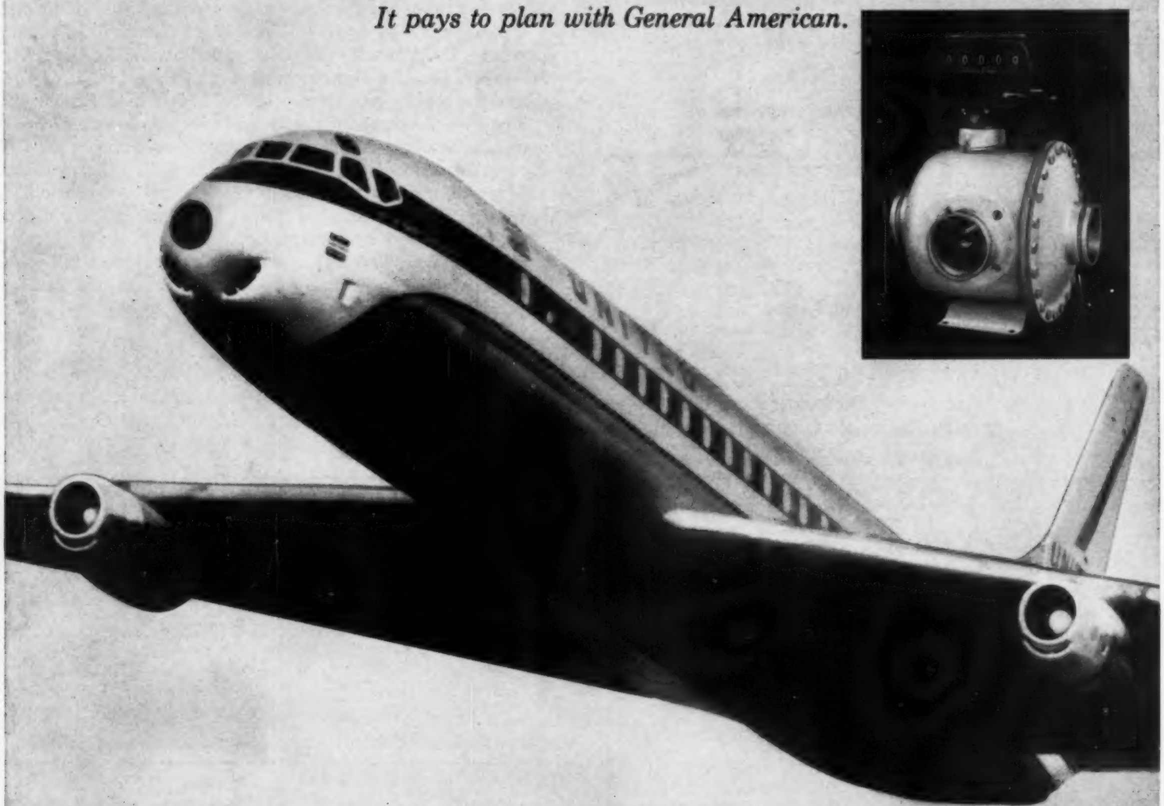
helps keep jet aircraft where the money is ...in the air

Big jet aircraft make money only when they are in the air. Every minute they are earthbound is costly. You just can't take chances on failure of aircraft engines from fuel contamination, or on failure of refueling equipment. That's why those parts of Brodie BiRotor refueling meters and control valves that come in contact with the fuel are chemically plated with KANIGEN nickel alloy.

Brodie BiRotor meters have been used for controlling aircraft refueling for many years, and their internal parts have been KANIGEN-coated ever since this highly accurate method of plating difficult or complicated surfaces was perfected.

Do you have a corrosion or contamination problem? Is it a small part like the Brodie meter housing? Or is it a surface as large as the inside of a 20,000 gallon tank car? Whatever it is, there's a way to solve your problems with KANIGEN chemical nickel plating. Write or phone the nearest General American office.

It pays to plan with General American.



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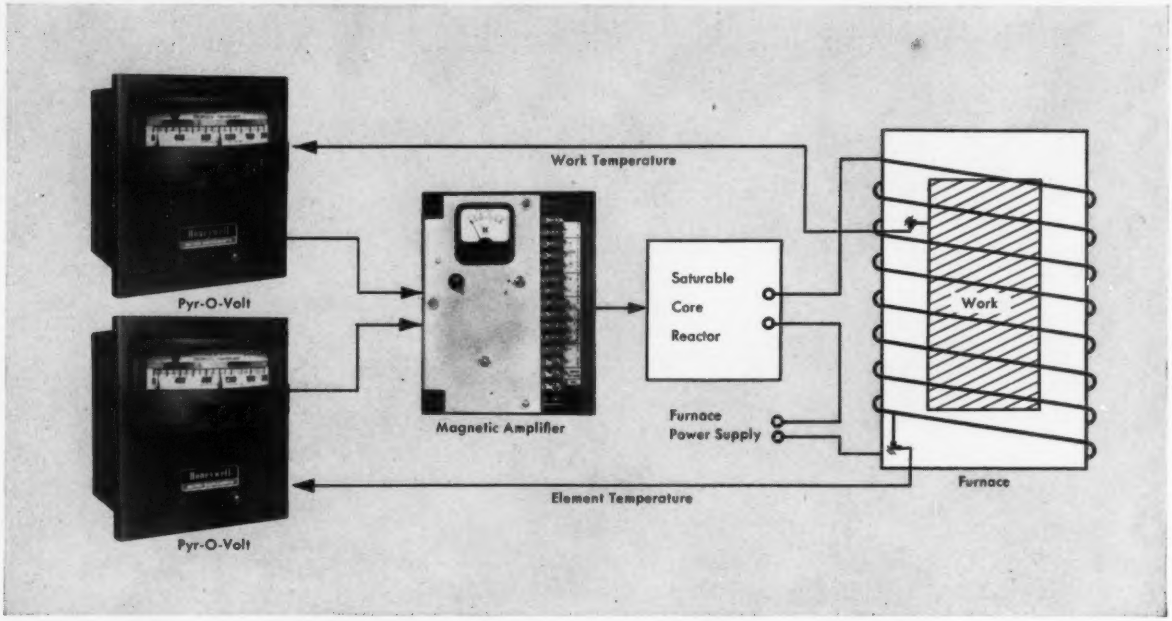


Electric furnace control system prevents overshoot, protects heating elements

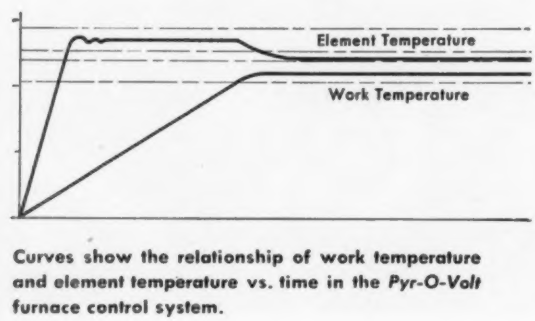
Here's the simplest, most economical way to bring electric furnace temperatures up to work level rapidly and safely using saturable reactor control.

This accurate Honeywell system holds fast-rising furnace temperature to a safe value as the slowly-increasing work temperature approaches its control point. The system consists of two *Pyr-O-Volt* controllers and a magnetic amplifier. Both controllers feed signals to the magnetic amplifier until work temperature reaches set point, then the work temperature controller assumes primary control of the system.

This relatively inexpensive system requires minimum maintenance, as no relays or other mechanical switching means are used. Both controllers have provision for fail-safe thermocouple burnout protection. In addition, automatic current limiting can be supplied with the system should you require extra protection for molybdenum heating elements.

Your nearby Honeywell field engineer can give you complete details on applying this system to advantage in your plant. Call him today . . . he's as near as your phone.

MINNEAPOLIS - HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.



Curves show the relationship of work temperature and element temperature vs. time in the *Pyr-O-Volt* furnace control system.

Honeywell

H First in Control

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Circle 1664 on Page 48-A

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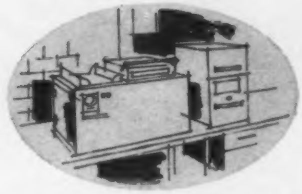
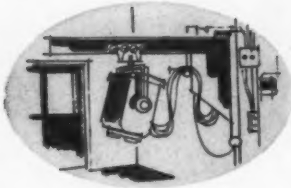
remote-inspection unit



Xeroradiographic unit for
dry-process radiography



OX-250 general
utility x-ray unit

Resotron 300*—
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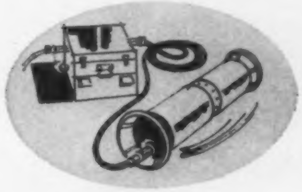
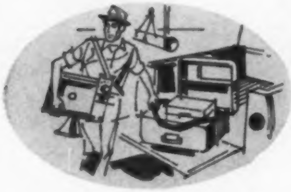


OX-175 — 175-kvp
portable x-ray



LX-140 — ultra-compact
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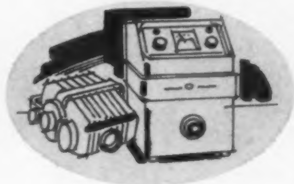

LC-90 lightweight
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Resotron 1000*—
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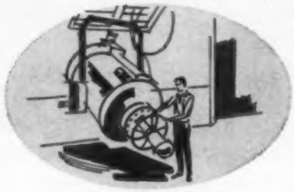

Resotron 2000*—
2-million volt x-ray

to look at your products!

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G-E x-ray inspection equipment covers every need — with units available in power ranges from 5 to 2,000-kvp output . . . choice of wet or dry radiographic processing . . . even *remote-television* x-ray fluoroscopy. Production-line, continuous inspection can easily be arranged where desired.

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For assistance with your inspection problems, contact our office in your area, or just write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, Room AS-54.

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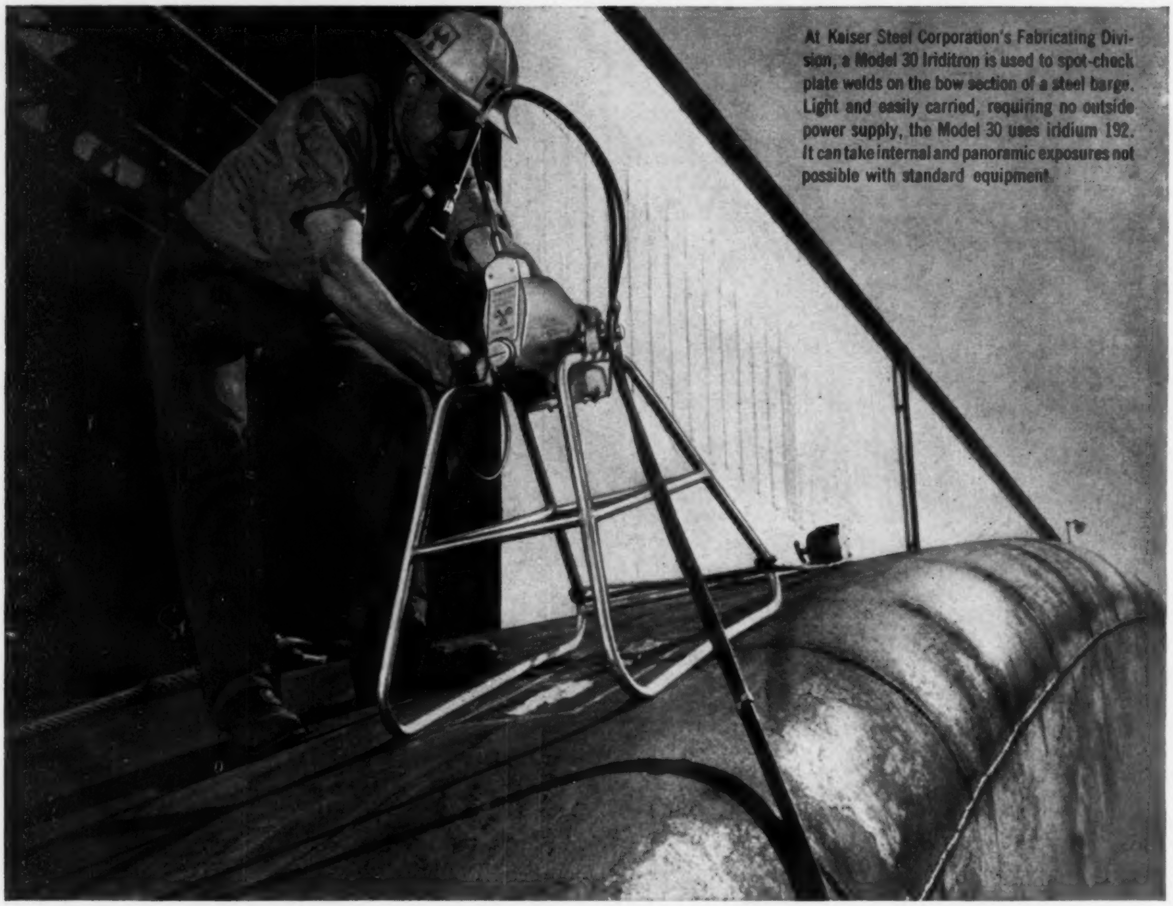
Circle 1665 on Page 48-A



Remote control of iridium...with Budd Iriditron units

- **Especially designed for remote handling of iridium 192**
- **Excellent for panoramic and internal exposure**
- **Permits exposure of iridium sources by remote control as far as 50 ft. away.**

Skid mounted or portable, this Budd Iriditron unit provides all the versatility of the traditional unshielded source for pipe weld radiography, panoramic exposure of multiple specimens, circumferential and longitudinal welds in boilers and pressure vessels. The unit can hold extremely strong sources... as much as 30 curies of iridium 192, approximately equivalent to a 260 KV X-Ray machine. This adds up to significant reductions in exposure times.

And you get complete service from Budd—including radioactive source supply and encapsulation, source replacement and disposal, training for your personnel (at no charge) and aid in setting up complete radioactive facilities.

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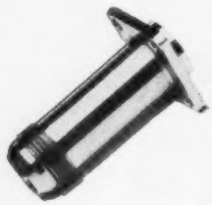
New user reports say once again... rely on Ryerson for increased values

Here are new case histories that typify how thousands of steel and aluminum users who rely on Ryerson get *increased values* for their purchasing dollars. Individual points of difference between Ryerson and other sources may not in every case seem overwhelming—but in total they add up to an important difference in dependability, experience and capacity to serve.

Production up 30%. In the manufacture of this coupling, a large job shop recently switched from MT 1015 tubing to Ledloy® 170 tubing from Ryerson. Machining speed was stepped up to 170 sfm, and production increased 30%.

Emergency needs met. A breakdown was cutting output of a big paint producer, and the steel needed to repair the break was not available in the area. However, the required analyses and size were on hand at the nearest Ryerson plant 200 miles away—and within an hour Ryerson delivered 100 feet of this bar stock to the local airport. Three and a half hours after calling Ryerson in another state, the customer had his steel.

Aluminum key to low-cost production. Aluminum from Ryerson replaced chrome-plated brass on this hub for a disposable hypo needle—saving two-thirds of basic material cost plus elimination of expensive chrome plating. Machinability was equal to that of brass.



Machined from one piece. This jet engine replacement part was machined as a single unit from Type 416 Stainless—2⅝″ Round, with excellent results and finish. Five operations were required to turn out the finished part. It was machined—blanked, drilled, threaded, and roughed out on back (square section)— from the Type 416 Stainless at *20% over recommended speeds,* using carbide tools.

Better product appearance and a worthwhile saving in material cost resulted when a Ryerson man recommended that a producer of portable coolers switch from one aluminum alloy (3003-H14) to another (5005-H14). Slightly higher structural strength was a bonus value. Unusually broad aluminum stocks and technical resources often enable Ryerson to serve in this way.

PVC cuts costs 50%. A screw machine shop recently replaced nylon with Ryertex®-Omicron PVC in the manufacture of a nipple adapter and coupling nut, and cut costs 50%. PVC machined better—to closer tolerances with improved finish . . . ran faster without "gumming." Note the perfect cutting of threads and barbs. Threads fit perfectly.

These examples illustrate some of the many advantages that make Ryerson service truly unique. A call to your Ryerson representative may solve similar problems for you.

METALOGICS

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Circle 1668 on Page 48-A

Metal Progress

Vol. 77, No. 5 May 1960

Technical NEWS in Brief

Auto Makers Set Pace in Materials and Processing

Trends in processing methods and materials used by the automotive industry were revealed by M. F. Garwood, chief engineer of materials, Chrysler Corp., at the recent Cleveland District Meeting of the American Society for Testing Materials:

Improved electroplating processes for auto bright work are now supplanting the conventional bright nickel-chromium systems. Chrysler Corp. leans heavily on duplex nickel followed by chromium and has notified vendors that the process will be the required plating practice for all bright plated parts on its autos by next year. It is estimated that steel parts plated with duplex nickel have a life four times longer than parts plated with conventional bright nickel.

Corrosion protection for auto bodies is also getting more attention. Plymouth bodies go through a six-stage spray and seven-stage immersion system (see photo) for rustproofing, then a seven-stage paint process.

Interest in aluminum engine blocks is strong. Chrysler has 10,000 of these on the road today in locations where it can keep an eye on engine performance. Made of A-380 alloy, the blocks are die cast, a process which Chrysler feels is the best way to achieve maximum economy and quality. No cylinder liners are used. Die-cast aluminum cylinder heads – possibly two-piece assemblies – can be expected.

Auto makers continue to drift away from high-alloy steels. For rear axle drive pinions, a newly developed steel, S.A.E. 4422, in which molybdenum is the only critical alloying element, has replaced S.A.E. 8620. Machinability and hardenability of the two steels are almost identical, yet the S.A.E. 4422 costs \$0.40 per hundredweight less. Another example of the trend from alloy steels is in intake valves. Some engine designs can use valves made of 1041 steel. To protect the valve face, it is metalized with aluminum, then induction heated to diffuse the aluminum into the steel.

Cold extrusion, which is growing rapidly, often permits use of more economical steels and frequently decreases heat treating since the properties

Better Rust Protection for Autos
Plymouth Body Dips Into Tank of Anticorrosive Solution

achieved by cold work may be good enough for the job. A typical example is a suspension control arm bushing where the switch from a machined, bored and broached part to a cold extrusion resulted in a $0.17 saving per part. One of the limitations of the cold extrusion process is that initial outlay for equipment is high and is justified only in high-volume production.

Welding has taken on new prominence particularly in the unitized body construction where almost 7300 spot welds are required. The change from the conventional frame in body construction to unitized design required extensive work in setting up welding practices. A difficult problem, for example, was to insure that spot welds were not only strong under static conditions but during dynamic loading as well.

Plastics are becoming more important in auto manufacture for two main reasons: Better plastics are available and their costs are moving downward (compared to metals where the cost trend is up). Radio grills, interior trim parts, and even carburetor float valves are being made of plastics. In auto finishing, plastics have proved valuable in the form of epoxy resin primers which are highly resistant to impact damage and to water penetration.

Spacer Springs of H-11 Solve Heat Treating Problem

Engineers of Boeing's Aero-Space Div. in Seattle, Wash., experienced trouble with distortion in heat treating thin-gage aluminum sheets. The problem was solved with springs made of H-11 die steel which are inserted at the top and bottom of the coils (see below) to hold the sheets firmly in position when they are placed on the furnace racks. Springs are made of wire 0.063 in. in diameter, and are 8 in. long with outside diameter of 1 in. They retain their tension through hundreds of heat treating cycles.

Spacer Springs Hold Coils
No Distortion in Heat Treating Thin-Gage Aluminum

Space provided by the springs between the coils insures uniform heat distribution and improves the circulation of quench water. By restraining the coiled sheets during heat treating, and at the same time preventing metal-to-metal contact, the spacer springs have minimized warpage and weak spots. The technique has improved the mechanical properties of heat treated sheets and has lowered the number of rejects.

More Facts on Explosive Forming

Lockheed Aircraft Co. has been investigating the fundamentals of explosive forming in a contract with the U.S. Atomic Energy Commission. Working with Vascojet-1000 sheet, 0.025 in. thick, and a cup-shaped die of 4130 steel hardened to C-36, Lockheed engineers found that the explosive should be fairly close to the work in order to get the most accurately formed shapes. Strangely enough, a paper coffee cup can direct the force of the blast and increase the attainable draw depth by 50%. If die, workpiece and explosive are immersed in water, the amount of work for a given explosive charge is also increased with more safety. The only measurable change in characteristics of the Vascojet-1000 sheet after explosion forming is a decrease in fatigue properties; normal work hardening ability is unimpaired.

Trends in Tool Materials and Metal Fabrication

Those who read the dozen or more brief articles on tool materials in this issue (p. 97) will note several important trends: In the first place, several of the steelmakers point out the growing use of air hardening tools because dimensional changes during hardening are minimum and uniform and the hardness is easier to standardize. Others note recent adjustments in alloy content to improve tools for specialized uses. Changes in steelmaking techniques such as vacuum casting and vacuum melting produce sounder metal — especially needed for the larger dies for forging, extruding and die casting — with much attention also to minimized segregation in the ingot. Carbide tools are all-but-universal for really high-speed cutting; users are finding that a tool having throw-away carbide inserts costs less per piece than when the cutting edges are reground. Finally, molybdenum-base alloys appear to have what it takes to forge and extrude the stiff high-temperature and refractory alloys so much in demand by the missile makers.

New Steel for Porcelain Enamel

Users of porcelain enamel finishes have long recognized the advantages of one-coat, one-fire enameling. In *Metal Progress* for June 1959, it was reported that Armco Steel Corp. was field testing "Univit", a special sheet steel for one-coat enameling. Armco announces that this new enameling iron is now in commercial production.

The most important property of the new sheet is freedom from fishscaling and boiling of the porcelain finish. This means that a single finish coat, in white or in color, can be applied directly to fabricated metal parts in one firing operation. The conventional ground coat required for most regular enameling grades of iron and steel is eliminated.

The new enameling sheet is expected to find wide use on appliances, where exposed parts subject to high inspection standards, such as range, washer and dryer tops, will have a smoother finish. In addition to cost reduction, another advantage is over-all reduction in thickness of the coating. Parts finished by the one-coat process will resist mechanical damage to a greater degree than those enameled by conventional two-coat practice.

Growth in Oxygen Blown Steel

In the March-April issue of Jones & Laughlin's informative Jalmet Notes we see that the process devised by C. V. Swartz of Germany and R. Durrer of Switzerland of blowing cast iron to steel in a basic-lined vessel by an oxygen jet impinging from above, and put into full production at the Linz-Donawitz plants in Austria in 1953, has now been so widely adopted that the world capacity exceeds 14 million net tons annually. American installations are:

Now operating	
McLouth Steel Corp.	1,385,400 net tons
Acme Steel Corp.	452,000
Kaiser Steel Corp.	1,440,000
J. & L. (Aliquippa)	880,000
Total operating	4,157,400
Under construction	
Colo. Fuel & Iron Corp.	600,000
J. & L. (Cleveland)	1,200,000
Grand total	5,957,400 net tons

Fluoroscope Tests Welds in Steel Pipe

Checking welded seams in steel pipe by X-ray inspection is a slow process and even then it is not necessarily representative since standard practice calls for inspection of only the end portions of the pipe. These shortcomings have been overcome by a continuous fluoroscoping process (see photo) employed as a regular production tool by National Tube Div. of United States Steel Corp. since January 1959.

FLUOROSCOPE INSPECTS WELDED PIPE
Continuous Process Permits 100% Inspection of Weld Seam

In operation, the equipment inspects 40-ft. sections of welded pipe. Source of radiation is an X-ray head mounted on a 48-ft. boom which surveys the weld from inside the tube. The image is picked up on a fluorescent screen, intensified, then televised. Convenient inspection is possible since the inspector views an enlarged image on a television monitor. When he detects a flaw, he simply presses a button which marks the spot with a water-soluble white paint.

Water Detection Device Makes Oil Quench Safer

Heat treaters know that they must not have water in an oil quench tank. Not only does slack quenching result, but water is actually a danger if the system is enclosed. If the moisture rises above 0.15% is an oil-filled tank, steam can form when a hot charge is quenched. Internal expansion may then cause foaming, and the 1700:1 increase in volume of water vapor within the oil can swell the entire volume beyond the limits of the quench tank.

To avoid this potential hazard, a device for detecting small amounts of water in oil has been developed by Ipsen Industries, Inc. This new safety feature, known as the Ipsen Water Sentinel, consists of a probe, the heart of which is a replaceable resistor sensitive to water. This probe is immersed in the oil and sealed in the tank. Whenever the amount of water in the tank rises above 0.10%, an audible or visual alarm operates immediately, or the unit is shut off.

Materials Progress in Direct Conversion of Nuclear Energy

As engineers search for new ways to generate power they are looking with increased interest at methods for converting heat directly into electricity without the need for moving parts, such as required by conventional generators. The reason: Quite recently, the development of new thermoelectric materials has raised both the power output and efficiency of thermoelectric devices to levels suitable for the practical generation of power. For example, Westinghouse states that a year ago it was working with devices whose output was slightly over 1 watt. Today, the company has generators rated at 100 watts and will soon complete a generator rated at 5000 watts.

Thermoelectric devices are actually used as an array of series-connected thermocouples, whose materials have been formulated so their voltages are additive. Some typical materials include zinc antimonide, the tellurides of lead, bismuth, manganese, and germanium. Other promising materials are nickel oxide containing 3% lithium and sumarium sulphide which shows good efficiencies up to 2000° F.

One of the most exciting possibilities is the use of the thermoelectric principle to convert the intense heat of nuclear fission directly into electrical energy. One way to do this is to expose the hot junction of thermoelectric devices to the hot fuel elements of a nuclear reactor and the cold junctions to the moderator-coolant water. As you might imagine, such a design poses a problem in selecting thermoelectric materials which behave properly under irradiation conditions. However, such materials are available and a number of them are being tested in research reactors.

An indirect method could be employed which would use the moderator-coolant water as the heat source. This means making a boiler with thermoelectric tubes instead of regular boiler tubes and connecting it to the nuclear reactor pressure vessel. The thermally hot, moderator-coolant water would flow down the center of the thermoelectric tube to heat the hot thermocouple junction, while the cooler secondary water would flow around the outer surface to cool the cold junction which would develop the temperature difference for power generation.

Another direct generating method can use the thermionic principle, which is relatively simple: Heat is applied to an electron emitting filament and the thermal energy from the heat of fission can be converted directly into electrical energy. A power generator built on this principle at the A.E.C.'s Los Alamos Scientific Laboratory has been operated for short periods. The nuclear reactor also offers an ideal heat source for magnetohydrodynamic and other direct conversion methods.

Dr. W. E. Shoupp, technical director of Westinghouse's Atomic Power Dept. sums up future possibilities this way: "On a long term basis, we believe that direct conversion of fission energy through thermoelectric and thermionic generators can become a reality for simple passive systems operating at high temperatures. The realization of this objective depends upon reactor progress and upon our ability to develop high-temperature structural and thermoelectric materials."

From Here and There . . .

メ タ ル シ ョ ー 協 会

It is too bad that news about the Fourth Osaka International Trade Fair did not reach us until after the April issue was closed, for the date is April 9 to 26. Our friend, Haruo Tonami, of the Japanese Scientific publishing house AGNE, who is also secretary of the Metal Show Assoc. of Japan, writes that the latter is sponsoring "The Metals' New Fashion Corner" in one of the halls. A visitor will also note other advantages which he points out: "April in Japan! It is warm and nice, and the best season for sightseeing; cherry blossoms in their full bloom and birds sing their songs merrily."

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If you are interested in vacuum melting and pouring, explosive forming, or cold forming processes, you may wish to take advantage of A.S.M.'s new electronic literature searching by the Documentation Service. Because these are "hot" subjects attractive to a number of subscribers, a very special price is offered of $200 for a year's subscription. For this you receive digests every two weeks of the world's current literature on any one of these subjects that you select. When search subjects are individually specified by the subscriber, the subscription rate is $50 per month.

Columbium Alloys Will Become More Important

Before 1955, scarcity of columbium caused both economic and governmental pressures to eliminate it from consideration in alloy development programs. Then, in the mid-fifties large deposits of columbium ore were discovered on this continent and on others. (This was one of the many positive gifts to humanity that have come from our efforts to satisfy the peculiar metallurgical needs of nuclear energy.) These discoveries increased the known columbium reserves to an amount which rival those of nickel. It's now predicted that by 1970, columbium alloys will be employed for most of the 1900 to 2600° F. structural applications. Total use will amount to several million pounds of mill products per year and alloy costs will drop to $15 to $20 per lb. In an article in next month's *Metal Progress*, L. P. Jahnke, manager, metallurgical engineering, R. G. Frank, manager, columbium project, and T. K. Redden, physical metallurgist (all of the Flight Propulsion Laboratory, General Electric Co., Cincinnati) will tell about results already achieved from the great effort now underway to expand our knowledge on columbium alloys.

Southwestern Metal Congress
Program of A.S.M. Technical Sessions
Dallas, Tex., May 9 through 13, 1960

Monday, May 9, 1960

9:00 A.M. – Sheraton-Dallas Hotel
Composite Materials for High-Temperature Application

"Metal-Metal Oxide Alloys for High-Temperature Applications", by *Nicholas Grant*, Massachusetts Institute of Technology, Cambridge Mass., and *K. Zwilsky*, New England Materials Laboratory, Medford, Mass.

"Metal Fiber Reinforced Ceramics and Metal-Ceramic Laminate Composites", by *J. R. Tinklepaugh*, Alfred University, Alfred, N. Y.

"Composite Materials for Thermal Protection", by *E. Scala*, Avco Research and Advanced Development Div., Wilmington, Mass.

2:00 P.M. – Sheraton-Dallas Hotel
Materials for High-Temperature Application

"Pyrolitic Graphite", by *R. J. Diefendorf*, General Electric Research Laboratories, Schnectady, N. Y.

"Selection of High-Strength Carbons for High-Temperature Applications", by *E. R. Stover*, General Electric Research Laboratories, Schenectady, N. Y.

"Design of Graphite Leading Edges for Hypersonic Gliders", by *Frank Anthony*, Bell Aircraft Corp., Buffalo, N. Y.

Tuesday, May 10, 1960

9:00 A.M. – Sheraton-Dallas Hotel
Steels for High-Load Applications

"Crack Propagation Characteristics of Cold Rolled High-Strength Stainless Steels", by *R. A. Lula* and *G. Aggen*, Allegheny Ludlum Steel Corp., Pittsburgh

"5% Cr Ultra-High-Strength Steel in Aircraft and Missiles", by *J. C. Hamaker, Jr.*, Vanadium-Alloys Steel Corp., Latrobe, Pa.

"Steels Heat Treated to 260,000 Psi. for High-Load Applications", by *F. D. Weaver*, Southwestern Industrial Electronics Co., Division of Dresser Industries, Houston, Tex.

2:00 P.M. – Texas Hall of State, Fair Grounds
New Frontiers Metal Processing

"The Carbon Dioxide-Shielded Metal Arc Welding Process", by *J. P. Koss*, A. O. Smith Corp., Milwaukee, Wis.

"Brazed Honeycomb for High Temperatures", by *H. R. Wiant*, Avco Research and Advanced Development Div., Wilmington, Mass.

"Pipe Line Welding", by *Robert S. Ryan*, Columbia Gas System Service Co., Columbus, Ohio.

"Gas Nitriding Stainless Steels", by U. S. Coppola, Cameron Iron Work, Inc., Houston, Tex.

Wednesday, May 11, 1960

9:00 A.M. – Sheraton-Dallas Hotel
Failure Analysis

"Die and Tool Failures", by *R. F. Spillet*, Crucible Steel Co. of America, Sanderson-Halcomb Works, Syracuse, N. Y.

"Special Heat Treat Techniques", by *J. Turk*, Paulo Products Co., St. Louis, Mo.

"Toughening High-Strength Steels", by *Henry Fuchs*, Metal Improvement Co., Los Angeles

"Sucker Rod Pin and Coupling Fatigue Failures", by *A. A. Hardy*, Sucker Rod Engineering and Research Director and *W. C. Norris*, Manufacturer Div., Dover Corp., Tulsa, Okla.

2:00 P.M. – Texas Hall of State, Fair Grounds
Testing at High Temperatures

"Thermodynamic and Physical Properties of Refractory Materials", by *C. L. Rosen*, *A. A. Hasapis* and *J. W. Wholley*, Avco Research and Development Div., Wilmington, Mass.

"Testing at Temperatures Over 2000° F.", by *D. F. Comstock*, Arthur D. Little, Inc., Cambridge, Mass.

Thursday, May 12

9:00 A.M. – Hotel Adolphus
Castings for High-Temperature and Corrosive Service

"Application of Shell Molding to Valve Bodies", by *Dale Davis*, Oklahoma Steel Casting Co., Tulsa, Okla.

"A Status Report on Project Vulcan—a New Approach to the Problem of Casting Complex Parts in High-Strength Metals", by *Herbert Greenewald*, Chance-Vought Aeronautics, Dallas, Tex.

"The Nature and Problem of High-Temperature Corrosion", by *John R. Schley*, Manager, Technical Services, Haynes-Stellite Co., Kokomo, Ind.

2:00 P.M. – Hotel Adolphus
Castings for High-Temperature and Corrosive Service

"Titanium Castings", by speaker from Oregon Metallurgical Corp., Albany, Ore.

Panel Session on Casting.

6:30 P.M. – Grand Ballroom, Hotel Adolphus
Dallas Dinner Dance

Tentative Program
Society for Nondestructive Testing
Dallas, Tex., May 9 through 11, 1960

Registration

Members – $3.00, Nonmembers – $5.00 ($2.00 applicable to membership)

Monday, May 9, 1960

9:15 A.M. – Baker Hotel, Crystal Ballroom

New Instrumentation and Techniques

"X-Ray High Speed Motion Pictures for Reliability Parts Evaluation", by *J. L. Minos*, Convair–Astronautics, San Diego, Calif.

"Nondestructive Chemical Analysis With the Electron Probe Microanalyzer", by *L. S. Birks*, U. S. Naval Research Laboratory, Washington, D. C.

"Design and Development of a Low-Frequency Eddy Current Thickness Tester", by *Paul Dick*, General Electric Co., Missile and Space Vehicle Dept., Philadelphia

"Magnetic Field Sensing for Testing Instrumentation and Control Applications", by *R. G. Hentschel* and *H. L. Carbarino*, Magnaflux Corp., Chicago

2:00 P.M. – Baker Hotel, Crystal Ballroom

"Parameters of In-Motion Radiography", by *B. A. Skelton*, Chance-Vought Aircraft, Dallas, Tex.

"Photomicrography of Small Radiographs", by *L. C. Wall*, Eastman Kodak Co., Rochester, N. Y.

"Advantages and Limitations of Thermographic Inspection of Brazed Honeycomb and Similar Structures", by *Robert Flournay*, Magnaflux Corp., Los Angeles

"Nondestructive Inspection of Jet Engine Parts With Eddy Current", by *R. L. Lipe*, Oklahoma City Air Material Area, Oklahoma City

"Optimal Radiographic Linac Designs", by *E. A. Burrill*, *J. H. Bly* and *J. C. Nygard*, High Voltage Engineering Corp., Burlington, Mass.

Social Hour – 6:30 P.M.

Tuesday, May 10, 1960

9:00 A.M. – Baker Hotel, Crystal Ballroom

"Helium Leak Testing Fuel Rods for the PWR Blanket", by *A. E. Oaks*, Westinghouse Electric Corp., Pittsburgh.

"A Precise Method of Making Elastic Constant Measurements and Its Application to Material Engineering", by *Ralph H. Kenton* and *S. Joseph Baranowski*, Magnaflux Corp., Chicago

"Determination of Thermocouple Locations in Re-Entry Vehicles Using Penetrating Radiation", by *M. V. Grund*, Avco Corp., Wilmington, Mass.

"A Metal-to-Nonmetal Sonic Bond Tester", by *Frederick Himmelstein*, General Electric Co., Missile and Space Vehicle Dept., Philadelphia

"New Developments in Ultrasonic Transducers and their Application to Nondestructive Testing", by *John P. Bacon*, Elion Ultrasonics, Bristol, Pa.

12:30 P.M. – SNT Luncheon

2:00 P.M. – Baker Hotel, Crystal Ballroom

"Determination of Ultrasonic Velocity by Immersion Method", by *D. E. Kaufman*, Los Alamos Laboratories, Los Alamos, N. Mex.

"A Plutonium Handling Facility for Radiography", by *A. L. Dighton* and *W. D. Stump*, Dow Chemical Co., Rocky Flats, Colo.

"Eddy Current Inspection of Missile Components", by *A. E. Supplee*, Aerojet General Corp., Sacramento, Calif.

"The Role of the Nondestructive Test Engineer in Design and Specifications", by *D. E. Elliot*, Los Alamos Laboratories, Los Alamos, N. Mex.

"Nondestructive Testing in the Metalworking Industry", by *W. F. Alderson* and *T. A. Giltner*, ACF. Industries, Albuquerque, N. Mex.

Wednesday, May 11, 1960

9:00 A.M. – Baker Hotel, Texas Room

"Nondestructive Testing Applications of Radiofrequency Spectroscopy", by *William L. Rollwitz*, Southwest Research Institute, San Antonio, Tex.

"Nondestructive Testing of Resistance Welded Oil Pipe", by *Bruce Dedman*, Lone Star Steel Co., Daingerfield, Tex.

"Nondestructive Testing of Tubular Products", by *W. A. Black*, Republic Steel Corp., Cleveland

"Ultrasonic Focusing Lenses and Their Application", by *R. C. Stinebring*, Westinghouse Electric Corp., Pittsburgh

2:00 P.M. – Baker Hotel, Texas Room

"Effect of Specimen Thickness, Cladding and Lift-Off Adjustment on the Conductivity of 7075-T6 Aluminum Alloy", by *D. D. Seltzer*, Martin Co., Baltimore, Md.

"The Potential of Thermal Techniques in Nondestructive Testing", by *J. R. Barton*, Southwest Research Institute, San Antonio, Tex.

"Detection of Particles in Liquids by the Use of Ultrasonics", by *Charles Albertson*, Grumman Aircraft Engineering Corp., Bethpage, N. Y.

"A Summary of the First National Symposium on Nondestructive Testing of Aircraft and Missile Components", by *William E. Cory*, Southwest Research Institute, San Antonio, Tex.

Stresses in High-Temperature Corrosive Environments

*By WILLIAM H. FUNK**

When used in a pressure vessel at elevated temperatures, steel plate clad with stainless steel will have a complex stress condition. However, experience with vessels in service indicates that such stresses are not detrimental. Tests and service data indicate that clad steels are good materials for refinery construction. (Q25, Q3, T29n; ST, SS, 8-66)

THE PETROLEUM AND CHEMICAL processing industries use a large amount of stainless-clad steel plate for their reaction vessels. The reason, of course, is simple. A low-carbon steel plate clad with a thin layer of corrosion resistant stainless is less expensive than a solid plate of the same stainless. Consequently, containers for hot corrosive liquids are frequently built with stainless-clad steel.

In applying stainless clad for any specific purpose, consideration of service conditions is very important. When a container is to operate at an elevated temperature, we must understand how the material from which it is made will behave when subjected to varying stresses. In this paper, we intend to review some of the characteristics of austenitic stainless clad plates as observed in testing and in service.

Types of Clad Steels

Several types of clad or lined steels are available, and have been available for a number of years. For the integrally bonded type, three production methods have been used. The writer's company produces "roll-bonded" clad by assembling the stainless cladding material in a "sandwich" between two slabs of steel. This sandwich, appropriately coated and protected to encourage bonding on the desired interfaces, is sealed by welding around

*Research Administrator, Lukens Steel Co., Coatesville, Pa.

the periphery. Then it is heated and rolled to bond the stainless to the backing steel.

Of the other two methods, one is no longer used. In this, initial bonding was achieved by casting one of the materials against the other in an ingot mold. This bimetallic ingot was then rolled to plate gage and size after heating. More recently, a brazing method (in which vacuum aids in producing an integral bond) has been developed. Though these three production methods all produce a clad product which has comparable characteristics, the first method is most widely used in industry.

By contrast, there are methods of making a *non-integrally* bonded plate. Two methods use resistance welding to produce spot welds at predetermined intervals across the face of the clad plate product. These spot welds may be spaced so closely that they overlap in one direction and almost overlap in all directions. They can also be spaced to make a pattern of spots 2 to 3 in. apart along the length and width of the plate.

Stainless sheet linings can also be plug welded to the inside of a steel vessel, or narrow strips of stainless sheet can be applied to the inside surfaces of a fabricated vessel. In the latter method, these strips are welded to each other and to the vessel wall.

Materials Used in Clad Steels

Selection of cladding materials is based on service requirements. These may demand several different characteristics. Along with being corrosion resistant, clad plates must be strong at elevated temperatures, must be easily fabricated, and must be economically satisfactory for the particular situation. Let us go back over the records and see just what types of materials in what gages have been used at some elevated temperatures. According to estimate, there are now more than 150 large vessels being used in the petroleum industry which are fabricated from the integrally bonded type of clad steel. Most of these have Type 304, 304 L or 316 stainless cladding in them. Temperatures range from 950 to 975° F. in catalytic reactors, and up to 700 to 800° F. in desulphurizers. Vessel wall gages range from ½ in. to nearly 4 in. in thickness, and the cladding thickness ranges from 5 to 25% of the total thickness. (In actual measurement, this is from 0.050 to 3/16 in.) Backing steels are one of the following: A.S.T.M. A-285, A-201, A-212, A-204, A-301, and A-387. As can be seen, these run from carbon

Table I – Stresses in Pressure Vessels Under Various Temperature and Pressure Conditions

Stress Location	10% Cladding*	20% Cladding*
	At 80° F.	
In plate, cladding	+30,500 psi.	+30,500 psi.
Backing	−3,400	−7,600
At joints, cladding	±30,500	±30,500
Backing	±33,500	±33,500
In plate†, cladding	+30,500	+30,500
Backing	+15,350	+11,150
At joints†, cladding	±30,500	±30,500
Backing	±33,500	±33,500
	At 800° F.	
In plate, cladding	−16,000	−16,000
Backing	+1,780	+4,000
At joints, cladding	±16,000	±16,000
Backing	±23,500	±23,500
In plate†, cladding	+2,000	+2,000
Backing	+19,789	+22,000
At joints†, cladding	±16,000	±16,000
Backing	±23,500	±23,500

*Type 304 stainless clad on A-204 C plate. Vessels stress-relieved after fabrication.

†Values at operating pressure. (Other values were taken at "no pressure".)

steel through silicon steels to carbon-molybdenum and chromium-molybdenum steels. The latter types are more suitable for elevated service. In other industries, clads of 18-8 types of stainless steel have been used where service temperatures have ranged as high as 1800° F.

Physical tests (such as shear tests on the bond line, bend tests with the cladding in tension and compression, and tensile tests) show that the stainless is bonded strongly to the backing steels after the clad plate is annealed at 1950° F. in the production process. According to A.S.T.M. Specification A-264, the shear strength between the cladding and backing materials is required to be 20,000 psi. minimum. Also, bend and tensile test results must demonstrate conformity to test requirements for the two materials involved. Actual shear strengths of clad plate will be as high as 45,000 psi. Additional tests on clad plates of 18-8 type stainless involved 20 cycles of heating to and quenching from 1800° F. There was no evidence of weakening or failure at the bond.

In further work, annealed samples of 20% Type 347 stainless-clad plate were heated at 1100° F. and water quenched to below 400° F. a total of 2000 times. Standard A.S.M.E. shear tests, which were made at intermediate points and after the 2000 cycles, indicated that the bond had not weakened or failed. Microscopic

examination showed that shearing usually occurred in the backing steel rather than along the bond line. This is understandable if we recognize that the nickel surface of the stainless steel cladding diffuses into and alloys with the backing steel. The strength of this band generally exceeds that of the backing steel.

Using the known characteristics of austenitic types of stainless steel and of carbon steel, it is possible to calculate the theoretical elongation and internal stresses which may occur in a clad plate when it is raised to a higher temperature. Under most conditions the stainless cladding will be restrained, because of its attachment to the thicker carbon steel. Internal tension stresses will develop in the cladding material as the temperature of the plate is raised. Inasmuch as the internal stresses in the clad plate must be in equilibrium, the stress in the backing material caused by the rise in temperature will be opposite in sign (compression). The magnitude relationship will be the same as the cladding thickness is to the backing steel; that is, with a 20% austenitic stainless clad plate, the stress in the cladding material will be four times the stress in the backing material.

To this point, we have been discussing stresses in a general manner. Let us now discuss a practical application. Consider, for example, a stainless-clad pressure vessel which is heat treated immediately before placing it in service. Usually, this treatment will be for stress-relief, and the stress-relieving temperature will generally be from 1000 to 1150° F. In a clad vessel at room temperature after a stress-relief treatment, the cladding is at or near the cold yield strength in tension, and the backing material is under some slight compression stress.

Knowing this, we can determine the stress situation which would result when heating the vessel up to 800° F. In Table I we show the probable stresses* in 10% and 20% Type 304 stainless cladding on A-204 grade C backing material at both 80 and 800° F. Stresses in the clad plates of an assumed vessel, in an area free from the influence of external loads or restraints, will be greater, in general, than they would if the same vessel were made of carbon, alloy, or stainless materials. However, inasmuch as we know that vessels are not fabricated without some residual stress existing at joints or at areas of discontinuity, even after stress-relieving, it is pertinent to look at the comparison of stresses at these locations. When we do this, we discover that maximum stresses are the same, whether the stressed material is carbon, alloy, or stainless material, or whether it is stainless-clad material.

Concerning the possibilities of creep in the clad vessels, our conclusions concur with the stated opinions of others who have studied this subject. We feel that creep in clad plate is no greater and no more detrimental than that which would be observed for plates of carbon, alloy, or stainless steels under the same operating conditions.

Clad Cylinder Tests

These opinions are reinforced by some test results observed after cycling stainless-clad cylinders between 200 and 1000° F. These cylinders were 8 in. O.D. by 12 in. long, clad with Type 304 on the inside. Two different methods were employed in making the weld joints.

After heating and cooling the cylinders through 1000 cycles, the clad plate was tested. Tensile strength, yield strength, elongation and reduction of area where the same as observed before the testing was begun. The bond strength of the cladding to the backing steel also had not been adversely affected, while examination (by microscope) of the materials in the cylinders showed no change in structure and no indication of fissures.

Also, in the weld joints there were no indications of any structural deterioration or fissuring. Apparently, the weld joint is not critically affected by thermal stresses if it is made according to normal good procedures.

Experience at 1500 to 1800° F.

The previous test, however, was limited because the cycling procedure did not allow a hold at 1000° F. To ascertain what would happened if a clad were held for a longer time at an elevated temperature, practical experience

*It will be noted that the table shows no stresses above the yield point for the materials considered. Actually, according to the calculations, this is somewhat in error. For example, in the 10% Type 304 stainless-clad vessel, the calculated stress in the cladding at 800° F. with no pressure is 50,000 psi. compression. Under such a condition, it is very possible that the yield strength of the stainless dominates the actual stress level. and the internal stress in the cladding due to thermal expansion will be about 16,000 psi. It means additionally that the stresses in both the cladding and the backing materials do not change in value in a linear manner when going from one temperature to another several hundred degrees above or below.

is needed. As mentioned earlier, there are some instances where austenitic types of stainless-clad steel are being used at temperatures above 1500° F.

In some metal reduction processes, retorts, clad with Type 304 stainless, are used as an enclosing chamber. Vertical during operation, these retorts are suspended from a flange near the top of the vessel. Operating conditions call for cycling from 100° F. to at least 1500° F. two or three times daily. After a number of cycles, it is natural to expect that distortion caused by weight will make necessary some reworking. These stainless-clad retorts can be resized several times before they must be permanently discarded because the wall is too thin, or the cylinder section is too long. Service life of the retort, including the resizing, has not detrimentally affected the bond strength of the clad plate.

As another example, rectangular tanks fabricated of stainless-clad steel are used for salt baths. In various shops, these salt baths will range from 1000 to 1500° F. Service conditions dictate, of course, that these bath temperatures be maintained for long periods of time without cooling down. Austenitic-type stainless clad steel plates have held up very satisfactorily under this type of service condition.

Laboratory Work Confirms Theory

Several years ago, an evaluation program was sponsored in an independent industrial laboratory to confirm the theoretical data previously discussed. Specifically, thermal expansion and internal stress data were desired. For this purpose, test cylinders were fabricated. One was 10% Type 304 stainless clad with A-201 B backing steel; the other was 20% Type 304 stainless clad with A-285 C backing steel. After rolling to shape, the cylinders were welded with one longitudinal seam so that the stainless weld metal did not penetrate below the bond line of the clad plates. Annealing and air cooling from 1950° F. followed fabrication.

Testing was done in an electrically heated oven which was provided with ports along a side wall so that optical measurements of expansion could be made of the cylinder as it was being heated and cooled. Gage marks, 24 in. apart, were placed on the outside of the cylinder wall. For the test, a cylinder was suspended in a loop of chain at both ends so that it was free to move in an unrestrained manner when the temperature changed. Actual temperature measurements were made with iron-constantan thermocouples embedded into the walls of the test cylinders.

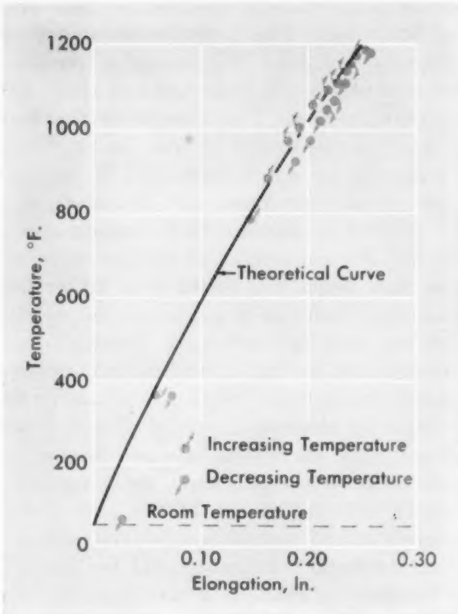


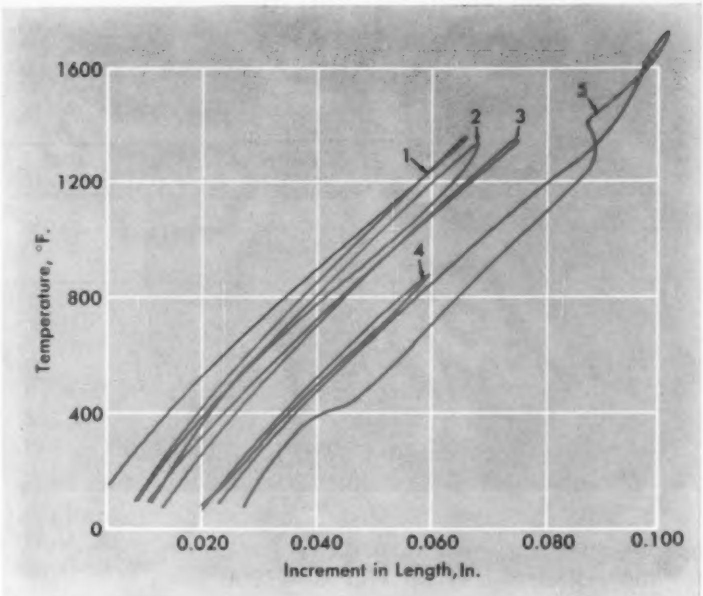
Fig. 1 – Expansion of Clad Steel With Change in Temperature. In this test, actual values depart from the theoretical curve because the zone of plastic deformation is entered (at about 1100° F.). A 20% clad cylinder was used in this test

As temperatures were raised and lowered, the distances between the gage marks were measured at intervals approximaetly 100° F. apart. Maximum expansion in the 10% clad cylinder at 995° F. was 0.180 in. and in the 20% clad cylinder at 992° F. was 0.182 in. These measured values conform very closely with the computed expansion.

In a third test (made with the 20% clad cylinder), the specimen was heated to 1237° F. to determine whether some plastic deformation might take place at this temperature. The results of this test (Fig. 1) suggest that at about 1100° F. the cylinder movement deviated from the elastic curve. Upon return to room temperature, there was a permanent elongation of about 0.027 in.

These tests, made under exacting procedures, demonstrated that the clad plate when heated will actually respond in a manner which can be calculated.

Fig. 2 — Thermal Bauschinger Effect on Clad Steel. Curves 1, 2, and 3 represent runs in which the temperature exceeded 950° F. but stopped below 1400° F. About 0.004 in. growth resulted. In run No. 4, which stopped below 950° F., there was no growth. When the transformation temperature is exceeded, as in run No. 5, another characteristic curve results. However, there is always permanent growth when 950° F. is exceeded



In our own laboratories, we examined still further the phenomena of short-time creep or plastic deformation at elevated temperatures. With a dilatometer arrangement, small specimens of 15% Type 304 stainless cladding on A-285 backing steel were heated and cooled through various temperature ranges. These tests confirmed, in greater detail, observations made on earlier thermal experiments. The thermal Bauschinger effect* in stainless-clad plates, as shown in Fig. 2, is one more piece of evidence that stainless-clad plates will behave in a manner similar to other ferrous materials. These curves show that, on the average, each cycle of temperature exceeding about 950° F. is accompanied by a net growth of the sample of about 0.004 in. per cycle.

Other data show that the Bauschinger effect was manifest by heating above 950° F. with holding times (at maximum temperature) which range from 15 min. to 4 hr. The same order of growth per unit was observed in specimens with percentage of clad material varying from 8 to 27%. Also, it was observed that for more than 20 cycles of heating one specimen the same growth of approximately 0.004 in. per cycle continued to result.

*This is the phenomenon by which plastic deformation of a metal increases the yield strength in the direction of plastic flow, and decreases the yield strength in the opposite direction.

Conclusions

Test data from both laboratories and industrial service suggest that austenitic stainless clad steels have predictable behavior characteristics when subjected to heat. Even though the stainless cladding material and the carbon steel backing have different basic properties, the net effect in a composite plate form does not appear to be detrimental for service up to 1000° F. In observing that the stainless cladding material might very well be stressed at yield point levels when the material is hot (and even when it is in the cold condition), one must recall that this is not necessarily detrimental to the performance of the complete vessel. After all, great plastic deformations can only occur if the material yields throughout its whole thickness.†

Stress calculations in both the stainless cladding and carbon steel backing materials appear to be satisfactorily confirmed under test conditions. Stresses are theoretically of a low order of magnitude in the backing steel. Practically, they can be considered of secondary importance compared with the unknown level of stresses (probably of high magnitude) existing in areas of discontinuity in the pressure vessel.

†"Stresses in Welded Pressure Vessels", by W. P. Kerkof (N. V. deBataafsche Petroleum Maatschappij, The Hague, Netherlands), *Welding Journal Research Supplement*, January 1956.

Cladding Steel With Titanium
. . . a Progress Report

By J. L. MA and
*C. WRIGHT, Jr.**

Because it resists attack by many corrosive liquids, titanium in sheet form is an attractive material for vessels used in chemical and processing industries. However, its high cost makes it uneconomical for this purpose. The solution? Clad a thin veneer of titanium to low-alloy steel plate! When mechanical difficulties are solved, titanium-clad plates of many sizes and gages will be available. (L22; ST, *Ti*)

Because titanium resists corrosion by nitric acid, wet chlorine, sea water, and many other corrosive liquids, it is of great interest to the chemical, food, and other process industries. However, the high price of solid titanium restricts its use. The obvious answer is cladding. If steel could be successfully clad with a layer of titanium, this would offer not only considerable cost savings to potential users, but also a greater variety of gage and size of plates which are not available in titanium mill products alone.

However, to produce a strong bond many problems must be overcome. For one thing, titanium is a highly reactive metal. It absorbs oxygen, nitrogen and hydrogen at elevated temperatures, and is apt to form brittle intermetallic compounds with most of the common metallic elements. Of course, such compounds cannot be allowed in the bond zone if strong and ductile metallurgical bonds are to be achieved.

Despite these difficulties, we at Lukens Steel have been interested in titanium-clad steel for the past ten years. During that period, our success in producing satisfactory titanium clads on steel has ranged from fair to good. Since we were aware that titanium forms a brittle intermetallic compound with iron, most of our early work was done with what might be called "sandwich assemblies". In other words, we used a thin layer of some other metal between the titanium veneer and the steel base.

Titanium-Copper-Steel

Copper platings were employed in our first tests. We began work by electrolytically plating about 3 mils of copper on the surface of the

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Fig. 1 – Tension, Compression, and Side Bend Tests of Titanium Clad on a Low-Alloy Backing Steel. These 180° bends indicate that both the clad and the base steel remain ductile

titanium to be bonded to carbon steel. Hoping that the copper coating would bar diffusion between the titanium and the steel, we assembled the plates into a sealed sandwich. This was rolled from about 5 to 1 in. thick with one reheating.

However, the result was disappointing. The copper-plated titanium had not bonded to the steel. In fact, the titanium separated easily when it was tapped lightly with a hammer, and the titanium itself also fractured, indicating that it was extremely brittle. (This condition also existed in the as-received titanium strip.)

Titanium-Nickel-Steel

Next, we tried plating a nickel layer on the bonding surface of the titanium. Rolling temperature was held below 1500° F. and the time at temperature was limited to less than 1 hr. At a minimum reduction of 50% (by either pressing or rolling), we obtained titanium-clad steel bars with bond shear strengths ranging from 15,000 to 49,000 psi. This strength, however, dropped progressively when the clad was subjected to reheating cycles at 1350 to 1550° F. Similar experiments using chromium plating instead of nickel failed to produce a good clad.

Titanium Sponge on Mild Steel

We then attempted to clad a fused titanium sponge to steel plate by a vacuum fusion operation. The assembly was heated under vacuum to 2100° F. in 4 hr., held at temperature for 1 hr., and cooled to room temperature in 4 hr. Interdiffusion during heating formed a eutectic titanium-iron alloy, which in turn melted and spread over the surface of the steel plate. On cooling, the fused material formed a dense, integrally bonded coating of titanium-iron alloy.

By careful process control, a titanium-clad steel plate measuring 138 × 85 × 0.25 in. was successfully produced. The fused and sintered titanium coating was hard and brittle, but was ductile enough to be cold formed. Eventually, this large plate was formed into three shell sections, 48 in. in diameter and 46 in. high. However, the demand for this item (which was used in a reactor, incidentally) was too small to justify further development.

Titanium-Vanadium-Steel

Vanadium is one of the few elements that remain in solid solution with titanium over the whole range of composition. Also, no brittle intermetallic compound forms between the two. Obviously, such a system was promising.

We began our work with the Ti-V-Fe system by forming sandwiches of the three elements. A thin foil of vanadium (0.003 or 0.01 in. thick) was inserted between the titanium and the backing steel. Next, the sealed assemblies (protected by argon) were heated to 1700° F., and subsequently pressure-bonded on a hydraulic press. Clad formed by this method was extremely ductile, and negotiated 180° bends successfully. The clad bond also remained strong

Table I – Summary of Experimental Results on Titanium Clad Steel

Backing Steel*	Bonding Pressure	Shear Strength, Psi.			
		As Produced	After Reheating†		
			A	B	C
A-302	100,000 psi.	31,950	10,850	—	—
A-302	50,000	30,000	25,350	—	—
A-202	150,000	32,500	29,500	23,800	27,800
A-204	150,000	44,800	39,900	27,800	39,300
A-387 D	150,000	31,900	—	—	—
A-387 D	100,000	26,900	27,000	—	—
A-387 D	50,000	28,700	31,000	—	—
A-387 D‡	100,000	31,200	29,250	—	—
A-387 D‡	100,000	24,000	40,050	—	—
A-387 D‡	100,000	23,500	29,300	32,900	25,300
A-387 C‡	100,000	—	—	29,500	31,200

*A.S.T.M. designations.

†Reheating — A = 1400° F., 2 hr., air cool; B = 8 cycles of 1400° F., 2 hr., air cool; C = 1650° F., 30 min., air cool.

‡Test plate dimensions were 4 × 4 × ⅜ in.; all others were 2 × 2 × ⅜ in.

and ductile even after repeated heatings up to 1400° F.

Nevertheless, there are drawbacks. At present, vanadium foil or sheet is available only in widths up to 6 in. and costs $35 to $60 per lb. Thus, the titanium-vanadium-steel system remains commercially unimportant.

Silver is another metallic element that is relatively compatible with both titanium and steel, and bonds produced with silver have been successful – at least in the laboratory. However, the control of temperature, atmosphere and time of heating must be extremely exact to avoid excessive migration of the silver into the titanium. We feel it would be difficult, if not impossible, to duplicate the required conditions in mill-size production. Another reason for discontinuing this approach is the high cost of silver foil – $1.15 to $1.40 a troy ounce.

Titanium on Low-Alloy Steel

To date, the most economical and practical system we have developed is to clad titanium directly to a low-alloy steel such as A.S.T.M. A-202, A.S.T.M. A-204, or A.S.T.M. A-387, Grades C or D.* By using the sandwich techniques with any of these alloys as the backing steel, the writers have had notable success in producing strong and ductile metallurgical bonds between the titanium and the steel backing. The results of the experiments are summarized in Table I. All shear strengths of the titanium-clad steels so produced exceed the A.S.T.M. minimum requirement of 20,000 psi. for stainless-clad steels. In most samples, the bond strengths are little affected by reheating at 1400° F. Up to eight heating cycles of 2 hr. each were used in testing. Ductility of the clad steel is indicated by the successful 180° tension, compression, and side bends illustrated by representative samples in Fig. 1.

Metallurgically, it appears that either molybdenum or chromium in the backing steel slows the formation of intermetallic compounds between titanium and iron. Figure 2 illustrates

*These A.S.T.M. specifications refer to low-alloy steels used for boilers and other pressure vessels. All of these alloys contain 0.15 to 0.25% C. Chromium, manganese, and silicon are the alloying elements in A-202, molybdenum is the alloying element in A-204, and chromium and molybdenum are the alloying elements in A-387, Grades C and D. As for trade names, Chromansil, Croloy 1¼, and Croloy 2¼ meet A-202, A-387 C and A-387 D specifications, respectively.

Fig. 2 – Titanium Clad on Croloy 1¼ Low-Alloy Steel. On the left, the clad is in the as-pressed condition; on the right, the clad has been heated eight times to 1400° F. Each holding cycle lasted 2 hr. Etched in HF and HNO_3; 250 ×

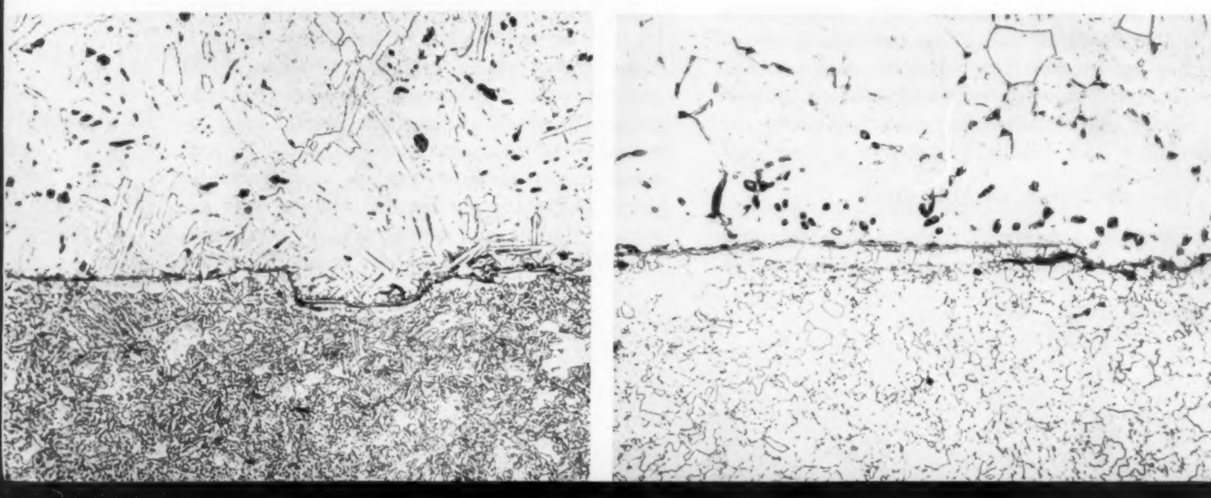

Fig. 3 – A Large Titanium-Clad Steel Plate, 135 × 49½ × 15/16 in.; Croloy 1¼ is used for the backing plate

the microstructure (as-pressed and after heating) of a titanium clad on a backing steel containing chromium and molybdenum (Croloy 1¼). Note that the intermetallic zone is relatively free of diffusion between the titanium and the steel.

Encouraged by the successful laboratory results, we made an attempt to produce a large clad steel plate, 135 × 49½ × 15/16 in. This plate, shown in Fig. 3, was 100% bonded in the as-rolled condition, as indicated by reflectoscope testing. Unfortunately, during later operations, the titanium absorbed hydrogen in the pickling bath and was embrittled so that the plate could not be successfully formed. However, laboratory tests have shown that the hydrogen in the titanium can be considerably reduced by vacuum degassing at 800 to 1550° F. Since our plant is not equipped to degas plates of this size now, the plate has been stocked until degassing facilities become available.

Subsequent attempts to produce titanium-clad steel in production facilities have been reasonably successful. Assembly size is also an important factor. For example, at the present time the size of the titanium-clad steel plates that can be produced with consistent properties is around 50 × 72 in., in gages of ¼ to 1 in. Beyond these limits, the results are somewhat erratic. Chief difficulties appear to be in mechanical design of the assembly to avoid contaminating the titanium during heating and rolling. These difficulties, however, are gradually being overcome, and larger plates of titanium-clad steel are expected soon.

If the clad plate is 100% bonded, hot forming should not be a problem. Figure 4 illustrates a dished and flanged head, 30 in. in diameter, formed from titanium-clad steel plate by pressing at 1200° F.

In conclusion, making titanium-clad steel by the roll-bonding method is technically feasible. Although the successes with the titanium-to-low-alloy steel bonding system are still limited by the plate sizes which can be made with consistent good quality, present difficulties are largely mechanical rather than metallurgical. When these are solved, steel plate clad with titanium will be available in many sizes.

Fig. 4 – This Flanged and Dished Head of Titanium-Clad Steel Is 30 In. Diameter. Backing material is A.S.T.M. A-204 low-alloy steel

Criteria for Selecting Metals Used in Chemical Plants

*By GEORGE A. NELSON**

There are about 60 ways metals can fail while exposed to the rigorous environments in chemical equipment. Most of the failures can be traced to metallurgical phenomena. The newer metals and improved alloys will broaden the horizons of the chemical processing industry. (T29m, Q-general, R-general, 2-62; SGA-g, SGA-h)

The metal most commonly used for equipment in oil and chemical plants is ordinary mild steel. The amount of special metals employed is, in general, quite small in comparison. For example, an estimate made a short time ago on the amount of special metals used by the oil industry revealed that 98% of the metal in an oil refinery is plain carbon steel. The balance – 2% – includes brass condenser tubes, stainless steel liners, and special fittings for corrosive services. It was also estimated that for every barrel of throughput each day, a ton of equipment is needed. Thus, a 100,000-barrel-per-day plant weighs 100,000 tons, of which 2,000 tons is of a special metal and the balance is carbon steel.

This illustration of special metals used in oil refineries does not apply to all chemical plants, which often require special materials to avoid corrosion, contamination or product degradation. Generally, it is estimated that chemical plants will use steel for 90 to 95% of their requirements. This includes all utilities, tankage and structural steel. The balance – 5 to 10% – will be special metals or nonmetallics.

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How Metals Fail

The ideal chemical plant is one that operates continuously at maximum capacity. This ideal situation is rarely attained, and shutdown of plants is required for maintenance of equipment. Some reasons for shutdown are fouling, loss of catalyst activity, metal failures and revamping of equipment. While many of the reasons for plant shutdowns are outside the interest of the metallurgist, there are numerous others in which he has a definite responsibility.

To determine the extent to which material failures have contributed to plant maintenance, a survey of eight chemical plants and nine oil refineries was conducted. To summarize the results, it was found that there are about 60 ways in which metals or equipment can fail while being exposed to the rigorous environments of the chemical industry. Most of the failures could be traced to metallurgical phenomena. There were other failures, such as deterioration of wood in cooling towers, leaking of gaskets and packing or failure of lubrication systems.

The metal problems were grouped under headings which designated the prime reason for the failures. By this method, a semblance

Fig. 1 — Carbon Steel Furnace Fitting Embrittled by Aging After Seven Years' Exposure at 800 to 900° F.

of order was indicated which offered a reasonable chance of developing criteria which could be used when a new plant was constructed or when an old plant was being remodeled.

Problem Areas Defined

Two outstanding categories of problems were established. These are *temperature* and *corrosion.* The most important factor is temperature, since it, above all others, produces changes in steel structures which render them unsuitable for use except in a narrow range. When accompanied by stress, or exposed to gases, the influence of temperature is magnified. Using the factor of temperature as the prime cause of failure, the following list of metallurgical factors was established:

Temperature Only

Transition temperature (brittle fracture)
Aging
885° Embrittlement
Graphitization
Sigma formation

Temperature Plus Stress

Creep
Thermal stresses
Thermal fatigue

Temperature Plus Gases

Air and oxidizing gases, such as steam, carbon dioxide and furnace gases
Hydrogen sulphide
Hydrogen
Hydrogen sulphide plus hydrogen
Nitrogen
Carbon monoxide
Vanadium pentoxide

Failures Attributed to Temperature Only

All of the problems created by temperature only are due to phases or structures initially present in the steel or to precipitation of compounds after exposure to high temperatures. The presence of these phases can result in brittle fracture.

Transition temperature has been widely studied, but even so commercially available carbon steel plates are generally unsatisfactory for prevention of brittle fracture. Carbon steel is prone to brittle fracture because of its crystallographic structure. Ferritic steel has a body-centered cubic lattice which has one cleavage plane and thus is sensitive to easy fracture. In contrast, austenitic steel, with a face-centered cubic lattice, has no cleavage planes and can fail only by shear.

Certain carbon steels are produced under controls which improve their transition temperature slightly. To improve resistance to brittle fracture, as a result of transition temperature, it appears that lowering the carbon content and raising manganese are beneficial. Boron, nitrogen and phosphorus seem to be harmful, whereas silicon, aluminum and nickel appear to be beneficial.*

Failures by brittle fracture can occur during hydro static testing when the vessel is overloaded and the water temperature is below the metal's transition temperature. A defect in a weld, if located at the proper point, can trigger a crack, then catastrophic failure results.

Aging results from precipitation of structures or compounds after the steel is exposed to elevated temperature for an extended period of time. Brittleness from these precipitates is particularly apparent at ambient temperatures. Thus, care should be exercised during shutdown periods to avoid sharp heavy knocks or jarring of equipment. When the plant is restarted and temperatures rise above 200° F.,

*"Pressure Equipment for Low-Temperature Service", by C. R. Soderberg, Jr., A.S.M.E. Preprint No. 58-MET-9, 1958.

ductility is again restored to the aging steels. Figure 1 shows the brittle appearance of a carbon steel fitting which broke after several years' exposure at 800 to 900° F. Fully killed steels having a minimum nitrogen content offer some protection against aging and strain aging failures.

Embrittlement at 885° F., occurring in high-chromium steels, is caused by precipitation of a chromium-phosphorus compound after exposure at 700 to 1000° F. The use of these steels at high temperatures is generally avoided.

Graphitization of steel is the breakdown of iron carbide into small particles of graphite and iron after extended exposure at elevated temperatures. The normal structures of carbon and low-alloy steels are metastable even in the annealed condition. The formation of graphite occurs very slowly at 850° F. and increases with rising temperatures with a maximum rate at about 1025° F. As a general trend, aluminum-treated steels (over 1 lb. per ton) are more prone to graphitization than silicon-treated steels.

Unless the graphite particles are arranged in a chain-like form, they are of no more consequence than the usual inclusions found in steel. However, near welds, the chain-like form may be present and brittle failure may occur. Failures by graphitization are rare; they can be prevented by using a steel containing a minimum of 0.70% Cr.

Sigma embrittlement in high-chromium and austenitic stainless steels is due to precipitation of an iron-chromium phase from free ferrite in the structure. Precipitation of this phase is principally along the grain boundaries; this causes brittleness, which is particularly evident when the plant is shut down for repairs. Sigma may be found in heat resistant castings used for tube supports and in furnace fittings operating at about 1200° F. Sigma formation in high chromium-nickel alloys is considerably reduced by the use of a balanced composition of A.S.T.M. Specification B-190. Other alloys which are free from sigma-forming compounds are also available.

Another type of brittleness in ductile steel

Fig. 2 – Cross Section of Furnace Pipe Shows Creep Due to Flame Impingement

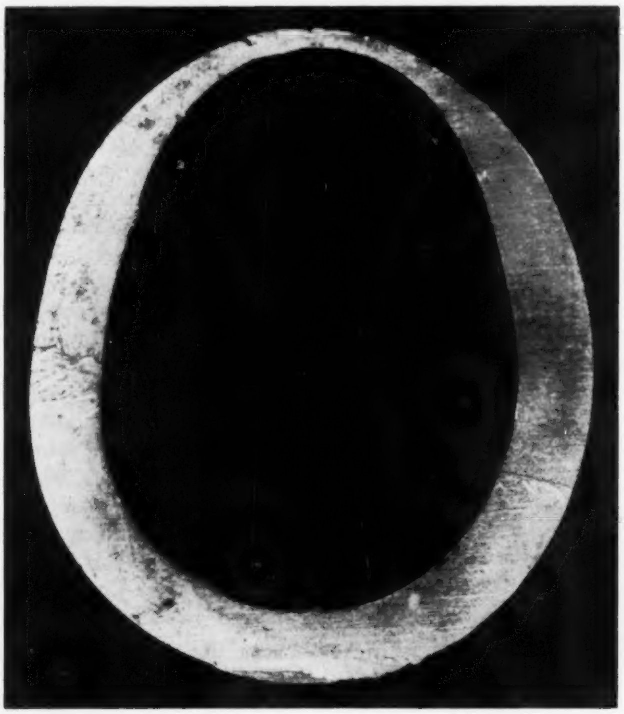
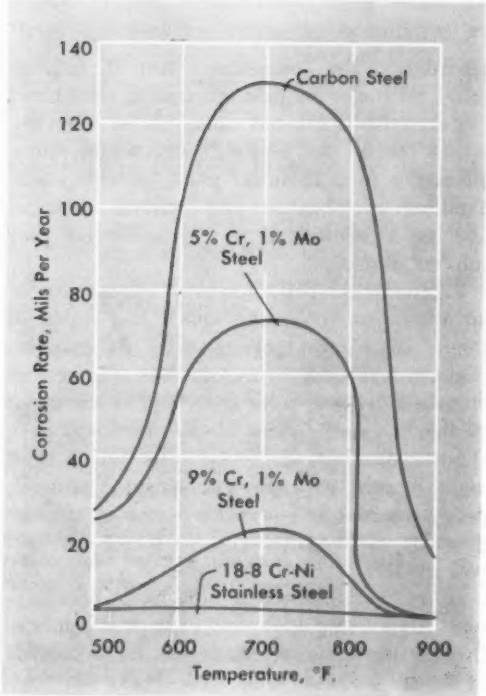


Fig. 3 – This Stainless Tube Was Exposed to 1300° F. on the Outside While Transporting Water on the Inside. The shocks of repeated strains by the boiling water caused failure of the tube by thermal fatigue



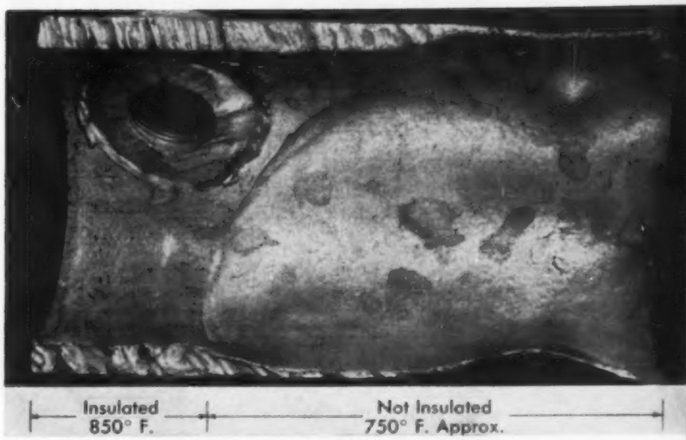


Fig. 5 — Section Through Carbon Steel Pipe Handling Oil Containing Sulphur. A part of the pipe is in the 850° F. range where no corrosion takes place compared with slightly lower temperature where corrosion is very heavy

Fig. 4 — Comparison of the Corrosion Rates of Different Steels in the 550 to 900° F. Range in Crude Oil Containing Sulphur

Fig. 6 — Operating Zones for Carbon and Alloy Steels in Hydrogen Service

*Residual Stresses in Heat Exchanger Tubes**

HEAT EXCHANGER AND CONDENSER TUBES are widely used by the oil and chemical industries. An estimate of the amount used in oil refineries has shown that about 40 ft. of tubing is required for each barrel of installed capacity. With U.S. refining capacity of 8,000,000 barrels per day, this amounts to 320,000,000 ft. of tubing. The tubes are usually steel, admiralty metal, or 18-8 stainless steel. Size is generally ¾ in. O.D., 16-gage wall, with lengths running up to 20 ft.

These metals usually perform well, giving service for five to ten years and sometimes longer. In some instances, however, the operating life has been very short – a matter of a few weeks. Failure in many of these instances has not been caused by excessive corrosion but has been due to fine pitting followed by prolific cracking. These cracks are found in both longitudinal and transverse directions. They are typified by a branched transgranular crack indicative of stress-corrosion cracking.

To investigate the problem, a subgroup was appointed by Subcommittee IX of A.S.T.M. Committee A-1 on Steel. A few examples of failed tubing will be given to illustrate the problem.

Brass – Several failures of brass tubing were reported to the committee. Not all failures could be traced to process streams containing the commonly blamed ammonia or mercury salts. Trouble was reported with a lubricating oil cooler in a chemical plant, in equipment handling cyclohexane plus sodium chloride, and in a system of propylene-butane plus sulphur dioxide.

Figure 10 (p. 134) shows the appearance of an admiralty brass tube which had failed in steam condensate service after 11 months. Failure was from the outside. Traces of ammonia (5 ppm.) were suspected as the cause of the cracking. General corrosion was very slight. Another admiralty tube failed after eight months in a process stream containing propylene and butane with traces of sulphur dioxide. A myriad of cracks along the wall was evident.

In another instance, a tube made of aluminum brass failed after one year in steam condensate service. Sea water was on the inside of the tube. Many transverse cracks were evident. In addition, other examples were reported of components which had failed due to fabrication stresses in the rolled area, severely bent coils, and in finned tubing which was highly stressed.

Carbon Steel – Failures of carbon steel tubing were principally confined to the area immediately around the rolled-in section.†

* Based on a report presented by Mr. Nelson at the A.S.M. Golden Gate Metals Conference, San Francisco, Feb. 6, 1960.

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results when temperatures drop to very low levels. Considerable processing of gases is done as low as $-320°$ F. While there are certain types of carbon steel which can be produced to have ductile properties down to $-50°$ F., the use of other metals is required beyond this point. Austenitic steels, aluminum, copper and nickel alloys are all ductile down to $-320°$ F.

Problems Arising From Temperature Plus Stress

When stresses are applied to metals while at high temperature, several problems are encountered. Creep in metal below the yield point is created by four factors: *(a)* metal temperature, *(b)* stress, *(c)* metal composition and *(d)* strain rate.

The phenomenon of creep is a plastic deformation in the grain structure of the metal. Below 700° F., creep is not appreciable in carbon steel; accordingly, wide use of this metal is found in this range with allowable stresses based on ordinary tensile test information. Above 700° F., creep becomes significant and allowable stresses are set at levels where appreciable deformation does not occur.

These stresses are established by the A.S.M.E. code which has allowances for creep and creep-rupture strength. Very critical design limit is considered to be 1% in 100,000 hr., although 1% creep in 10,000 hr. is often used. Carbon steel creeps at 700 to 1100° F., and molybdenum is added to give alloys with higher strength. Above a temperature of 1100° F., carbon steel oxidizes rapidly and highly alloyed materials

The services reported were those involving caustics at high temperature. For relief of stresses created by rolling-in operations, a thermal treatment was advocated. Where thermal stress-relieving cannot be done and caustic solutions are on the outside of the tubes, a recommendation was made that rolling be stopped ¼ in. from the back side of the tube sheet.

An example of accelerated corrosion as a result of stress is illustrated by two pieces of pipe in a line handling strong sulphuric acid, which had been welded together. One piece developed heavy corrosion with a Lüder line pattern while the piece on the opposite side of the weld showed no Lüder lines and no corrosion. Although no tests were made, it was inferred that the uncorroded pipe had been annealed at a sufficiently high tempera-

†The "rolled-in section" is the area immediately to the front or back of the tube sheet. In fabricating heat exchanger elements, the tube sheets or plates are drilled with sufficient holes for insertion of the tubes. Holes are usually 0.007 to 0.010 in. larger than the outside diameter of the tubes. After tubes have been inserted, the ends are expanded to a tight fit by means of expanding rollers. In this operation, expansion obviously stretches an area immediately back of the tube slot which is expanded from its original diameter to the new diameter of the hole in the tube sheet. The stresses in this area are of yield point magnitude, and with this high stress level, many failures have been reported. At the front of the tube sheet, it is sometimes the practice to "flare" the tube ends for purposes of streamlining the flow of the entering liquid. In critical services, the "flares" have cracked.

The portion of the tube confined between the front and back of the tube sheet very seldom gives trouble. Mechanical analysis of the forces encountered in this area show the metal to be under compression. Since stress-corrosion cracking can only occur in material in tension, this compressed zone should be free from cracks.

Stress-Corrosion Cracking in Stainless Pipe, Due to High Tension Stresses

with adequate creep strength are required.

In addition to pressure, creep is also caused by flame impingement, fouling by coke deposits on the inside of pipes, corrosion, poor burner settings and inadequate control of air and steam during thermal decoking cycles. Insufficient spacing of tube supports may cause tubes to sag from creep. Figure 2 is an example of creep of a furnace pipe due to flame impingement.

Thermal stresses develop when the expansion or contraction that would normally result from heating or cooling of a body is prevented. Many pieces of equipment are subject to cracking failure by thermal stresses. Such items as vessel openings, piping and vessel supports, and piping systems should be carefully studied to assure that temperature distribution through the sections is uniform.

Thermal fatigue, another problem associated with temperature, is damage caused by repetitive thermal stresses. The thermal strains produce plastic deformation during heating and cooling cycles. The effect of cumulative plastic strains eventually leads to failure by many cracks.

Failures of this type are encountered in high-temperature equipment subjected to many chilling cycles. Figure 3 shows a stainless tube exposed to 1300° F. on the outside while transporting water on the inside. The shocks of repeated strains by the boiling water cause failure of the tube.

Problems From Temperature Plus Gases

Ordinary steel resists practically all gases at ambient temperature. It is the standard mate-

ture to relieve critical stresses while the corroded piece had not.

Stainless Steel – Of the reports of failed austenitic stainless steel received by the committee, practically all were from services containing chlorides although one had been in caustic service. Failures occurred adjacent to the tube sheet from stresses created by tube expanders. They also occurred on portions of tubes some distance from the tube sheet. Failure here was attributed to stresses imposed at the tube mill during straightening operations. One failure was due to operational stresses.

The photograph on p. 85 shows stress-corrosion cracking on the inside of a short piece of stainless pipe, where high tension stresses are evidently present. Cracks proceed halfway through the wall where they are stopped by compressive forces. Such a condition can exist in an annealed tube where the outer layers are in a state of high compression with the inner fibers in tension.

Stress Consideration – It is apparent from the failures which have been reported to the committee that tension stresses are present in tubes which are of sufficient magnitude to induce stress-corrosion cracking in critical environments. Stresses come from three sources:

1. Residual stresses from manufacture. These were traced to the practice of straightening after the final anneal.

2. Stresses created during fabrication. Many forces are exerted during fabrication of heat exchanger bundles which can leave the equipment in a high state of stress. Some of these are: *(a)* rolling stresses at the tube sheet, *(b)* high stresses at bent sections of U-type bundles, and *(c)* uneven patterns of tightening tubes into tube sheets leaving some tubes in tension while others may be in compression.

3. Stresses from operation. Thermal gradients across tube walls can lead to high stresses. Also, certain tube bundles with fixed tube sheets may leave tubes in tension during shutdown periods. Exposure of such tubes to aqueous environments may lead to failure.

Since it is the prime objective of the A.S.T.M. committee to determine methods of producing stress-free tubes that will be reasonably straight, principal attention has been devoted to the first item. Tests were conducted to find the amount of stress in tubes after roll straightening. Following this, a study was made of annealing practices to eliminate stresses.

The split ring test appears to be the simplest way to reveal hoop stresses. The method of making this stress measurement is rather simple. It consists of cutting a sample about 3 in. long from the tube, measuring its outer diameter accurately, splitting it longitudinally with a hack saw on one side, and measuring its outer diameter again. From the change in diameter, the residual hoop stress in the tube can be calculated from the following formula:

$$S = \frac{E}{1 - V^2} d \frac{\Delta D}{Dm^2} \qquad \text{where:}$$

S = stress in outer fibers in psi.
E = modulus of elasticity in psi.
d = wall thickness in inches
V = Poisson's ratio
ΔD = change in diameter after splitting in inches
m = mean diameter

Samples of new tubing made to A.S.T.M. specification and tested by the split ring method

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rial approved by the Interstate Commerce Commission for the safe transportation of almost any dry gas. However, exposure of steel to the action of gases at elevated temperatures presents many problems, and limits must be set to indicate its limitations.

Oxygen – Oxidation by air or other gases increases the valence in the metal as a result of reactions between the metal and an oxidizing agent, usually oxygen. The rate of oxidation of carbon steel increases rapidly above 1000° F., and above this temperature, steels which form a resistant oxide film (stainless steels) are required. Temperatures considered satisfactory for long-time service in ordinary environments are given below for various metals:

Metal	Maximum Temperature
Carbon steel	1050° F.
5 Cr, 0.5 Mo	1150-1200
12 Cr	1300
18 Cr, 8 Ni	1450
25 Cr, 20 Ni	1650
Incoloy	1700

These limits may be altered depending on composition of furnace gases. Oxidation rates of steels in an open muffle furnace are sometimes higher than in a refinery furnace. Data for material selection should be obtained in

Residual Stresses in Brass and Steel Tubes After Annealing

Sample	Treatment	Hoop Stress
	Admiralty Metal — Specification B-111 ¾ in. × 15 gage	
1	Annealed at 1100-1175° F. after cold drawing	−1300 psi.*
2	Annealed, straightened on Mackintosh-Hemphill machine	4900
3	Annealed, straightened on Medart machine	4250
4	Same as (2) but reannealed at 1100-1175° F.	500
5	Same as (3) but reannealed at 1100-1175° F.	−1800
6	Same as (2) but reannealed at 1200-1275° F.	1950
7	Same as (3) but reannealed at 1200-1275° F.	−650
	Carbon Steel — Specification A-179	
1	Annealed, before straightening	0 to −2900
2	After straightening	4000 to 5000
3	Stress-relieved at 1150° F. after straightening	0 to −1400†
	Stainless Steel — Types 304 L and 316	
1	Annealed	−16000 to −18000
2	After straightening	7000 to 8000
3	Stress-relieved at 1650° F. after straightening	0 to −1300†

*(−) indicates compression stresses in outer fibers.

†The data recorded for the steel and stainless are only those at which the stress level changed to a compression value. Other tests had been made by annealing at lower temperatures but stresses were still in tension.

showed the following residual hoop stresses:

Admiralty Metal — Specification B-111	
1 in. × 14 gage*	9000 to 11,000 psi.
¾ in. × 16 gage*	5500 to 9000
⅝ in. × 16 gage*	3000 to 5000
Carbon Steel — Specification A-179	
¾ in. × 16 gage*	4000 to 5000
18-8 Stainless Steel — Specification A-269	
⅞ in. × 16 gage*	3000 to 18,000
¾ in. × 16 gage*	14,000 to 18,000
1 in. × 16 gage†	14,000 to 19,000

* Seamless. † Welded.

In connection with the above, it is significant that one of the ¾-in. brass tubes (Fig. 10, p. 134) had failed by stress-corrosion cracking in 11 months. Split ring tests made on an uncracked section showed a residual hoop stress of 4900 psi. This is below the values for average ¾-in. diameter admiralty tubes as indicated above.

Residual stress measurements have been made on brass and steel tubes after various annealing treatments. Table above gives data on hoop stresses.

The final phase of the program is to install tubes with varying amounts of stress into environments where cracking has occurred. This will test the efficiency of the stress-relieving treatments in preventing cracks. Depending on the results of tests, specification changes to incorporate this type of tubing will be considered by the committee.

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specific furnaces and in specific atmospheres.

Effects of Hydrogen Sulphide and Hydrogen — Steel is widely used in plants processing crude oils containing high percentages of crackable sulphur compounds such as mercaptans or polysulphides. When these oils are heated, hydrogen sulphide is produced. It attacks steel, at an accelerated rate in the range 550 to 900° F. with a peak at about 750° F. This type of corrosion can be reduced to tolerable rates by the addition of chromium to the steel. Figure 4 shows a comparison of corrosion rates with different types of steels in the 550 to 900° F. range in crude oil containing sulphur. Figure 5 shows a carbon steel pipe which has operated with sulphur-containing oil in the temperature region where no corrosion takes place, compared to a slightly lower temperature where corrosion is very heavy.

Hydrogen — For processing streams containing appreciable amounts of free hydrogen at high pressures, carbon steel has its limitations. Under the influence of temperature, atomic hydrogen develops, which diffuses into the steel. By reaction with iron carbide, methane is produced which cannot diffuse out of the steel. High internal stresses result, which eventually crack the steel internally at the

grain boundaries. Hydrogen attack is prevented by the addition of carbide-stabilizing elements. Fortunately, a wide range of chromium-molybdenum steels is available for use in the higher temperature regions. Figure 6 gives the limits for carbon and alloy steels in hydrogen service.

The phenomenal growth of catalytic re-forming of gasolines into a major oil refining process has led to widespread investigations of corrosion by hydrogen sulphide in the presence of high-pressure hydrogen. It appears that when the temperature rises above about 600° F., appreciable corrosion occurs on carbon steel and low-chromium steels with no advantage being gained by the addition of chromium. This is in contrast to the behavior of the metal when no free hydrogen is present. Corrosion resistance is obtained in the high-temperature region by the use of stainless steel or aluminized coatings.

Troubles From Nitriding and Carburizing

The gas which serves a useful purpose for hardening steel in the nitriding process also damages equipment in ammonia plants. Nitriding occurs above 800° F. on low-chromium and austenitic steels after long exposures. It is typified by a hard brittle layer which extends to a depth of about 1/32 in. This thin layer is of little consequence on heavy piping and forgings; however, thin pieces of equipment such as heat exchanger tubes, gaskets and expansion bellows cannot operate with hard brittle layers present.

No complete answer to this problem has been found. Many alloys have been tested, including Inconel, Hastelloy B and C, and other special metals. All have nitrided except the special metals containing cobalt, Haynes alloy L 605, for example. Nickel plating is a deterrent and will protect for about five years. Austenitic steels are less prone to nitrogen absorption than chromium steels. They are used particularly in equipment for higher-temperature operation. Figure 7 shows the brittle appearance of a nitrided case on the inner surface of a pipe as revealed by a crush test.

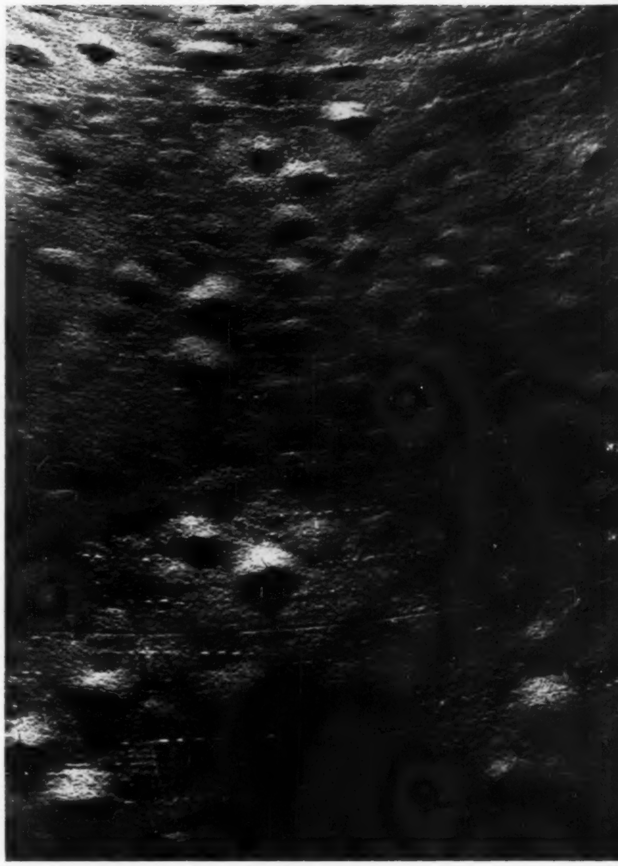
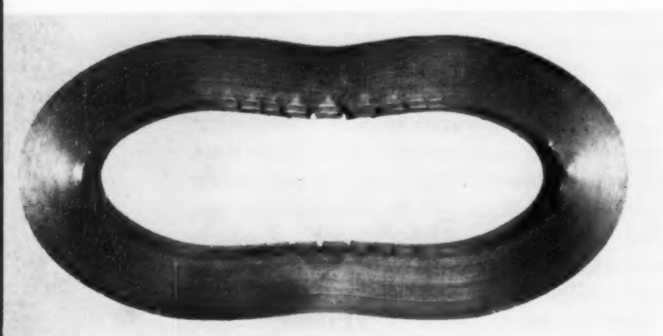


Fig. 8 – Wall of Steel Pressure Vessel Showing Hydrogen Blisters

Fig. 7 – The Brittle Nature of a Nitrided Case on the Inner Surface of a Pipe as Shown by the Crush Test



Carburization – Diffusion of carbon monoxide into steel and subsequent combination with iron is a widely used reaction to harden wearing parts. In heat treating operations, it is performed around 1650° F. but in chemical plants a damaging effect due to a breakdown of hydrocarbon fractions occurs as low as 1200° F. Generally, the carburized layer does not detract significantly *(Continued on p. 134)*

Flight in the Thermosphere–III

Materials for Ablation, Sublimation and Transpiration Systems

By WILLIAM S. PELLINI
*and WILLIAM J. HARRIS, Jr.**

These absorptive systems have a high effective heat capacity due to the utilization of the high values of the heats of melting, vaporization and dissociation. The sublimation potential of graphite, one of the best materials, may be limited by exothermic oxidation. (P12r, P11k; SGA-h)

ABSORPTIVE SYSTEMS TO BE DEALT with in this article have the highest heat flux capabilities – higher than exhibited by the heat sink systems which were discussed in *Metal Progress* last month. These systems also have the highest effective heat capacity, Q^*, of all absorptive systems. Their outstanding features are due to the utilization of the high values of the heats of melting, vaporization and dissociation. The emittance component of the ablation and transpiration type is generally low; in fact it is insignificant compared to the absorptive features. The sublimation types may involve an appreciable radiative component, depending on the material.

In order to utilize the heats of change of state for heat absorption, it is necessary to avoid loss to the air stream of semimolten material. This property is inherent to materials which sublime directly from the solid state or those which develop only a very thin film of liquid when they vaporize. For other materials of the ablative or subliming type, composite or heterogeneous mixtures are required which provide for mechanical retention of the melted material during vaporization. Retention of the vaporizing fluid is inherent to the design of transpiration systems and is provided by the fine pores through the aerodynamic wall surface.

Composite Systems

Steurer† has described possibilities of composite or heterogeneous systems based on a high-melting-point low-conductivity matrix which will retain pockets of lower-melting-point materials with high heats of vaporization. Matrices of beryllium oxide, zirconium oxide, titanium carbide and graphite with a fine scale distribution of beryllium, boron, aluminum and titanium pockets are examples. Calculations indicate that heat capacities of many nonmelting, homogeneous heat sink materials, which are in the order of the heat capacity value for water – 1000 Btu. per lb. – may be increased to 2000 to 3000 Btu. per lb. by such heterogeneous combinations of inorganic materials.

These principles may also be applied to

*Mr. Pellini is superintendent, Metallurgy Div., U. S. Naval Research Laboratory, Washington, D. C., and Dr. Harris is executive director, Materials Advisory Board, National Academy of Sciences, Washington. Previous articles in this series covered requirements for thermal protective systems (March); heat sink systems (April). The final article, next month, will deal with materials for radiative systems.

†"Criteria in the Selection of Materials for High-Temperature Structures", by W. H. Steurer, A.B.M.A. Report DV-TN-67-58, July 1, 1958.

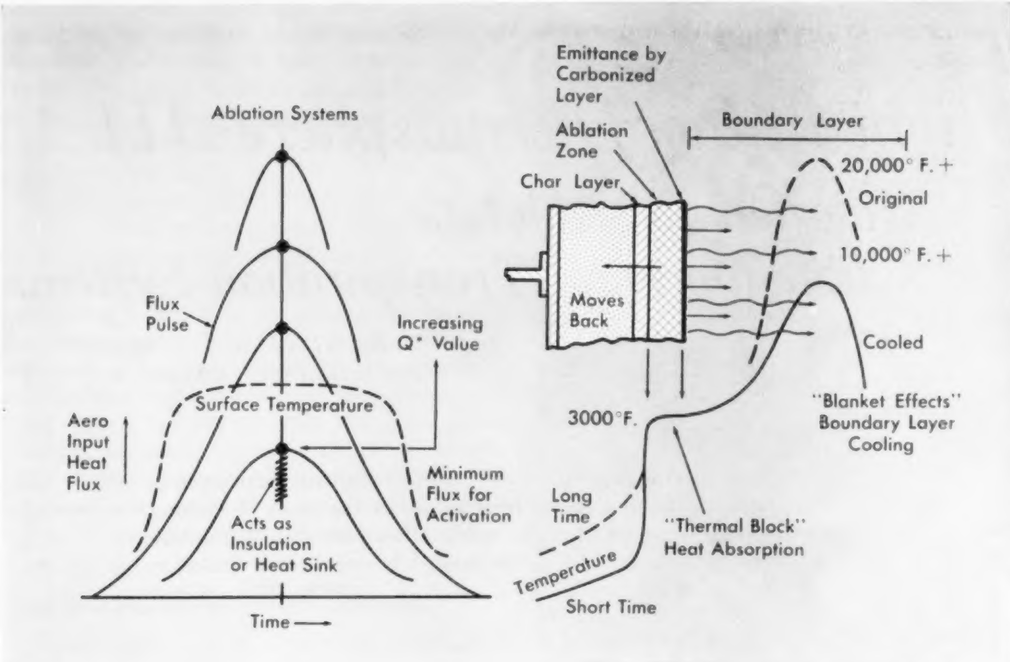


Fig. 1 – Thermal Principles of Ablation Systems Are Illustrated Above. If the ablation process is not activated, the material serves as insulation and as a low-grade heat sink. Required temperatures to activate the decomposition process may be in the order of 2000 to 4000° F. for heterogeneous mixtures of organic and inorganic materials. Q (effective heat capacity) is total aerodynamic heat input (Q) divided by weight loss in material*

heterogeneous combinations of organic and inorganic materials, plastics with glass fibers, for example. For such combinations, the decomposition process involves these steps: (*a*) Pockets of the organic material volatilize while held in place by an inorganic matrix having a higher decomposition temperature; (*b*) the inorganic skeleton volatilizes exposing the new surface; and (*c*) the two-step process is repeated.

Ablation Systems

The thermal principles of ablation systems are shown schematically in Fig. 1. Various heat flux pulses of increasing q-max value are represented, with the lowest value defined as being too low for the development of a minimum surface temperature required to activate the decomposition process. The required temperatures may be in the order of 2000 to 4000° F. for heterogeneous mixtures of organic and inorganic materials.

If the ablation process is not activated, the material serves as insulation and as a low-grade heat sink. In such an instance, the material is said to act as a "transulation" system, that is, nonsteady-state insulation. With higher heat flux pulses, the activation temperature needed is attained and decomposition of the organic and inorganic composite starts. This characteristic surface temperature, noted as 3000° F. for discussion purposes, can be thought of as a thermal block temperature which holds over a wide range of q-max values; if the heat flux is increased, the ablative process simply proceeds at a faster rate without any increase in surface temperature.

As the gaseous products of ablation are injected into the extremely hot boundary layer, further decomposition and dissociation to a plasma-like state may be expected to occur, with consequent very high heat absorption. The resulting "blanket" cooling effect lowers the average temperature of the hot gas layer, and the heat transfer rate is greatly decreased. The effective heat capacity, Q^*, of an ablation device therefore must be measured in terms of the sum of decomposition and dissociation

effects. If the "blanket" effect is disturbed by air stream turbulence, a decrease in effective heat capacity is probable.

The problem of using ablative devices for long-time exposures is illustrated by the curve for internal temperature rise, noted as "long time" in Fig. 1. The gradual increase in backside temperature with time may cause breakdown and disintegration of the organic material.

The general aim in the development of ablation materials is the achievement a high effective heat capacity, defined in the chart in Fig. 1 as Q^*. The limits of heat flux capability are not an inherent problem, as described for heat sink systems, because increases in heat flux activate more energetic ablation reactions and thus increase the rate of ablation. A possible limiting factor is an excessive ablation rate which could result in undesirable contour changes. The requirement for low ablation rates obviously requires materials with a high capability for effective heat absorption.

Features of Sublimation Systems

The ideal sublimation material has a high heat of sublimation, low conductivity, and it will sublime directly without entering the liquid state. Various ceramic materials have this property. Sublimation systems are generally high-flux devices because a high rate of heat flux is required to activate the process. Intermediate flux levels may destroy the sublimation material by heat penetration to cause thermal shock failure. Ideally, the materials should sublime faster than the rate of heat flow to subsurface region. Magnesium oxide is an example of a material having high sublimation heat coupled with characteristics which may result in thermal shock failure. Graphite has the highest theoretical heat of sublimation of all materials being considered. It is some 25 times more than the heat of vaporization of water; in contrast, other prominent sublimation materials have heat capacities only about one half this value.

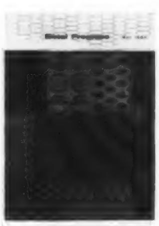
Problems in the use of graphite arise from its relatively rapid oxidation at elevated temperatures and its excessive conductivity for sublimation system applications. The problem of conductivity for a material like graphite, which is highly resistant to thermal shock, is due to the fact that the thickness, and thus the weight of the system, may be determined by the backside temperature rather than by the amount of the wall thickness which is vaporized.

Principles of Transpiration Systems

In transpiration cooling systems, liquid or gas is pumped through a porous skin. The coolant makes the skin act as a heat sink of very high specific heat capacity. As the gas emerges from the pores, it provides a blocking action which cools the hot boundary layers. Because the heat absorption takes place at the aerodynamic interface, there is no theoretical top limit to the heat flux. The potential limit is very high and depends essentially on the pumping rate and volumetric heat capacity of the coolant.

The most efficient liquid metal for transpiration cooling is lithium which has a heat of vaporization in the order of 30,000 Btu. per lb. Sodium, which is competitive with lithium for convective cooling, because of its higher conductivity, is not at all promising for transpiration cooling since its heat of vaporization is only

On the Cover



Myriad of Aluminum Designs – Some striking examples of the fabricator's art of forming and coloring aluminum are portrayed on this month's front cover. The art, which includes mesh or expanded aluminum and other mesh-like patterns, was made available to *Metal Progress* by Lawrence S. Sewell, Jr., of the Aluminum Co. of America, Pittsburgh.

Mr. Sewell points out that some of these patterns are available from stock, some on special order, while others exist in experimental form only. However, all of the many variations they suggest can be mass produced. The patterns shown actually represent mesh openings varying in size from less than a quarter inch to two or more inches. However, size is no deterrent because any pattern can be made in any size – small or large.

The variety of finishes are equally striking. Most are anodized. The sample at top left is anodized black, with highlights sanded off. The pattern at bottom middle employs Alcoa's multifaceted "Spangle Sheet".

Manufacturers represented by samples on the cover are: Exmet Electrical Corp., Tuckahoe, N.Y.; Penn Metal Co., Parkersburg, W. Va.; Rigidized Metals Co., Buffalo, N. Y.; U. S. Gypsum Co., Chicago, Ill.

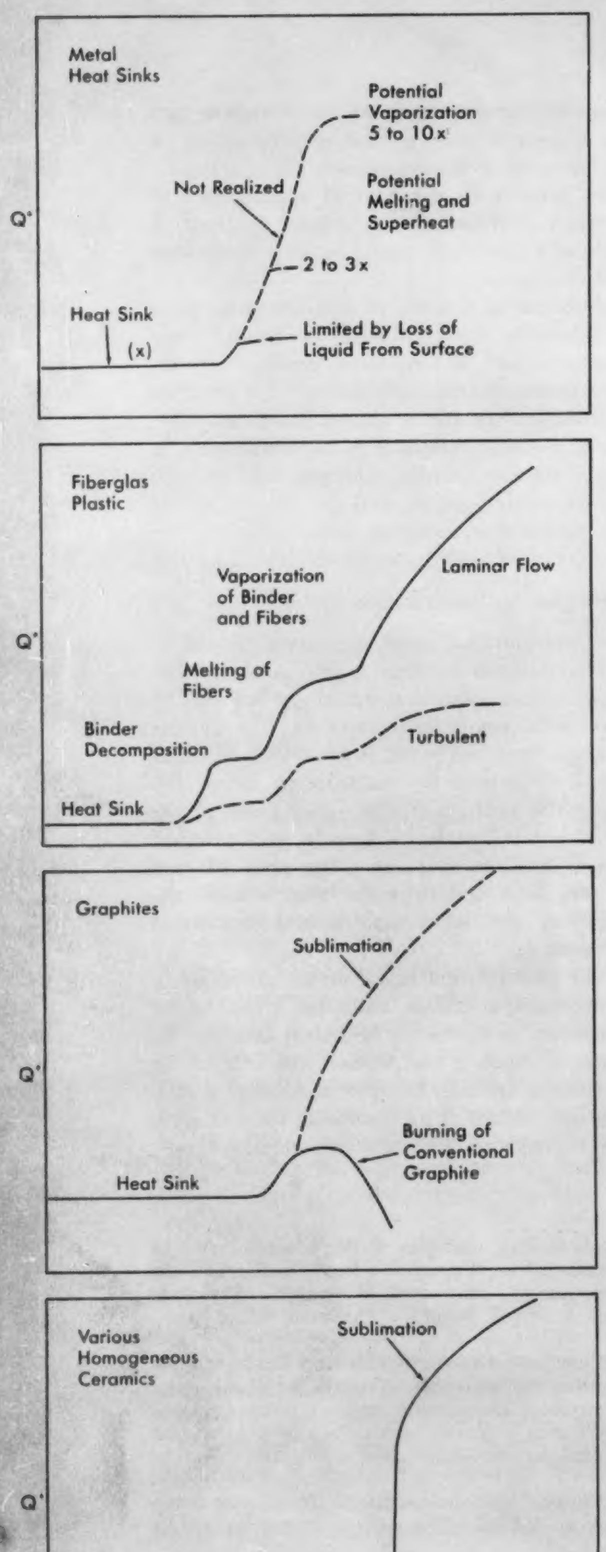


Fig. 2 – Charts Show Relationship of the Effective Heat Capacity (Q) of Intermediate and High-Flux Heat Absorptive Systems to the Level of Aerodynamic Heat Input* (q-*max*)

about one tenth that of lithium. Liquid helium and hydrogen may be considered for transpiration cooling on the basis of their high specific heat capacity and heat of vaporization. Even water is appealing, despite its low efficiency, because of simplicity of the pumping and container system.

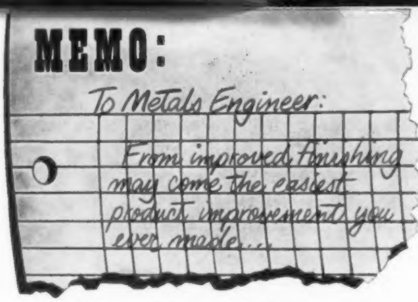
Controls Are Paramount

There are two main problems with transpiration systems: The fine wall passages needed for high heat flux conditions must be prevented from plugging, and the rate of coolant flow must be programed to match the incident heat flux. The slightest plugging, or mismatch of the coolant flow with the flux pulse, may result in melting of the wall. In contrast to the other absorptive systems discussed in this section, transpiration cooling is not self-adjusting to changes in heat flux conditions.

Relationships of Absorptive Systems

At this point, we may summarize the general relationships of the effective heat capacity, $Q^\star$, of intermediate and high-flux heat absorptive systems, as related to the level of aerodynamic heat input. The relationships of $Q^\star$:q-max are illustrated in Fig. 2. The charts are schematic and the scales are not quantitatively intercomparable. The limitation of heat sink materials to relatively low $Q^\star$ and q-max values is due to the requirement of preventing melting. The sublimation potential of graphites may be limited by exothermic oxidation which causes a net loss in $Q^\star$ value if the heat flux value is increased beyond the heat sink limit.

Ablation systems tend to activate more energetic decomposition processes with increases in heat flux; however, the portion of the increase which is due to "blanket" effects may be obviated by air stream turbulence. Sublimation devices based on homogeneous ceramics are for the most part very poor heat sink materials and are subject to thermal shock failure at fluxes below the activation point of the sublimation process. The sublimation process for such materials generally activates rather sharply when the heat flux reached is high enough to bring the surface to vaporization temperature.



No. 4 in a Series on Better Finishing

How to Get the Most From Solvent-Vapor Degreasing—Part II

*By T. J. KEARNEY and C. E. KIRCHER**

Solvent selection is just as important to effective vapor degreasing as is good equipment design. Such factors as boiling range, solubility of the soil and compatibility with the materials being cleaned are important. In this, the second of a two-part article, the authors also discuss specifications and costs. (L12j, S22, 17-53)

NO ONE SOLVENT IS SUPERIOR in all respects for the variety of industrial cleaning jobs which can be handled by solvent-vapor degreasing. For successful operation, it is essential to have the cleaning process designed for the particular job. Important factors are the amount and type of work processed, amount and type of soils on the work, and degree of final cleanliness required.

Just as important as equipment, mode of

*Mr. Kearney is chief engineer and Dr. Kircher is manager of research, Detrex Chemical Industries, Inc., Detroit.

Table I – Typical Applications for Vapor-Degreasing Solvents

Application	Solvent	Approximate Vapor Temperature	Factors Affecting Selection
Removal of soils from parts	Trichlorethylene	188° F.	Most commonly used degreasing solvent
Removal of slightly soluble (high melting) soils	Perchlorethylene	250	Used where higher operating temperature is desirable
Removal of water films from metals	Perchlorethylene	250	Rapid and complete drying in one operation
Cleaning coils and components for electric motors	Methyl chloroform Trichloro-trifluoroethane Perchlorethylene	165 118 250	Solvent must not damage wire coating or sealing agents. Requires special equipment design. Selection should be based on preliminary trials
Cleaning temperature-sensitive materials	Methylene chloride Trichloro-trifluoroethane	104 118	Used where parts must not be exposed to higher vapor temperatures during cleaning. Special corrosion resistant equipment is required
Cleaning components for rockets or missiles	Trichlorethylene	188	Cleaned parts must be free of soils or residues which might react with oxidizers
Cleaning with ultrasonics	Trichlorethylene Perchlorethylene Methylene chloride Fluorinated hydrocarbon	188 250 104 118	For cleaning efficiency beyond that obtained from standard vapor degreasing. Solvent must be kept clean by continuous distillation and filtration during use. Selection should be based on preliminary trials

operation and costs is the selection of the degreasing solvent, a critical factor in the overall analysis of a degreasing operation. In choosing a solvent, one should consider (*a*) solubility of the soils to be removed, (*b*) possibility of chemical action between soils and solvent, (*c*) metals or other materials to be cleaned, (*d*) equipment and solvent availability, (*e*) ability to recover or reclaim dirty solvent for re-use, (*f*) cost of solvent on a weight and volume basis, (*g*) solubility and compatibility of solvent with water, and (*h*) operating temperature range of the solvent. Table I shows how some of these factors enter into the selection of the commonly used solvents for industrial solvent-vapor degreasing.

Solvent specification and testing procedures are often misunderstood by the consumer because he is usually not informed on the technology of solvent stabilization. Before taking up any specific details, therefore, some general background information on these subjects is desirable.

It is not often that a chemically pure material is required or suitable for industrial use. Because of cost and other considerations, commercial products are refined only to the extent needed for specific applications. In many instances the performance of a relatively pure chemical is improved by stabilizers or modifiers. This applies to most vapor-degreasing solvents to which anti-oxidants and acid acceptors are often added. These stabilizers are not lost when the used solvent is put through a still to remove contaminants.

What is required for successful operation is not a knowledge of the formulation of the solvent but a specific and carefully prepared recommendation from the supplier as to how the solvent can be used most effectively to accomplish the desired cleaning results.

No Broad Specifications

There are no industry-wide specifications for degreasing solvents. Rather, each solvent producer has his own specifications. From one producer to another, however, these are generally quite similar in scope. There are several government specifications such as MIL-T-7003, O-T-634 a and O-P-191 which cover degreasing solvents. It is worthy of note that the A.S.T.M. has recently formed a committee, D-26, to study and prepare specifications on halogenated organic solvents. Its efforts in this direction could

Fig. 1 – Cleaning Refrigerator Tubing by Solvent-Vapor Degreasing. Load is first immersed in warm solvent, then vapor rinsed. Tanks behind operator are for storage and distillation of used solvent

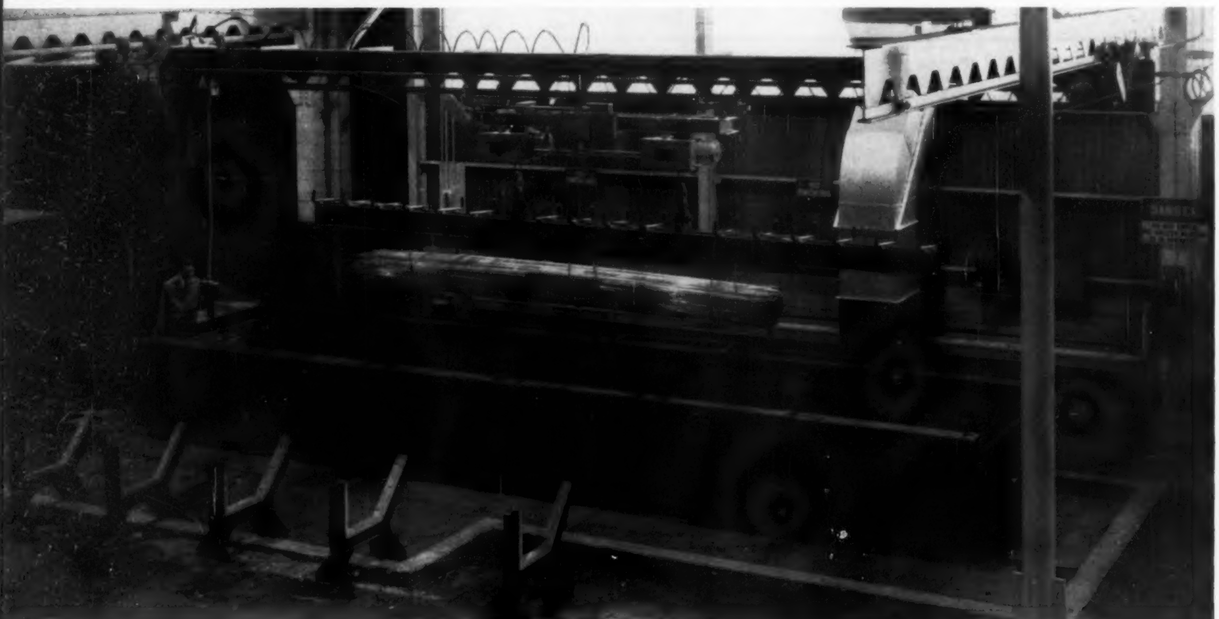


Table II – Specifications and Quality Control Guide for Vapor Degreasing Solvents

Specific Gravity, Refractive Index, Distillation Range: Definite value of pure compound. Variable value for mixture of compounds depending on composition. Specifying a range of values does not determine the composition of mixtures or identify what is in mixtures.

Residue on Evaporation: Shows amount of nonvolatile matter present either in solution or suspension. Since the stabilizers used in degreasing solvents are volatile, they are not in general the cause of residues. Soils picked up by solvents from containers and in transfer are the main source of residue.

Color: May be a characteristic of the initial material or may indicate some change taking place with time. Color change may or may not be indicative of product quality or performance, depending on the nature of the materials involved.

Cloud Point, Water Content: Indicates or measures the amount of water in solution in the solvent. In general this is not a critical or limiting factor for it should meet specifications.

Acidity: Determines the amount of acidic materials present by extracting them with neutral water and titrating the aqueous phase with standardized base to a stated end point. Acidity is important; it may lead to corrosion of parts and equipment.

Alkalinity: Determines the amount of alkaline materials present by extracting them with neutral water and titrating the aqueous phase with standardized acid to a stated end point. In new solvent this measures amount of amine stabilizer present.

pH Measurement: Determines the presence of acidic or alkaline materials by extracting them with neutral water and measuring the pH of the resulting aqueous phase. Does not identify the amount or type of acidic or alkaline materials present.

Free Halogen: Determines the amount of free halogen present in the solvent. Should be zero for present degreasing solvents. They cause serious corrosion.

Acid Acceptance, Amine: Amine stabilizer gives solvent pH greater than 7. Test measures the amount of acid (usually HCl) which will combine with additives in the solvent in the presence of water. The titration measures the amount of amine stabilizer in the solvent and the result is usually expressed as wt.% of equivalent NaOH corresponding to the stabilizer. (Inorganic alkalis are never added to halogenated solvents as stabilizers.)

Acid Acceptance, Non-Amine: A titration in anhydrous medium which measures the amount of epoxide or other stabilizer in the solvent capable of reacting with HCl under the conditions of the test. For uniformity the result is visually expressed as wt.% of equivalent NaOH corresponding to the stabilizer present.

Reflux or Storage Tests: This type of test can be run under a wide variety of conditions including low and high temperature and the presence or absence of water, metals, industrial soils, etc. In general such tests are intended to indicate how the solvent may stand up when subjected to actual plant operating conditions. The usefulness of the tests is limited by one's ability to duplicate plant degreaser conditions in a laboratory set-up and by the technical knowledge of the operator who must make the analyses and interpret the results.

ultimately result in generally accepted tests and specifications for trichlorethylene, perchlorethylene and other halogenated solvents.

Whether or not a specification has been met is best determined by standard test procedures. Unless the tests are technically correct and yield results which are reasonably reproducible and consistent, they cannot form the basis for a sound specification. Where possible, existing A.S.T.M. specifications are applied to solvents used in vapor degreasing. Examples of such tests are: For specific gravity, D-891-51; for distillation equipment, E-133-58; for distillation range, D-86-56 and D-1078-58; and for determinations of pH of aqueous solutions, E-70-52 T.

Additions Change Solvent Properties

As an example, let us consider the significance of some of the specification tests for trichlorethylene. Bear in mind that the commercial product is 99 to 99.5 wt.% trichlorethylene, with the balance made up of several carefully selected additives which have chemical and physical properties different from trichlorethylene. The specifications do not identify the specific additives placed in the solvent by the producer but they do provide a basis for

determining that a particular type or grade of stabilized trichlorethylene is being supplied.

The buyer, however, must know how to interpret the results of the specification tests. For example, consider the specific gravity of the solvent. Pure trichlorethylene containing no additives has a specific gravity of 1.470 at 15/4° C. However, unstabilized trichlorethylene is not acceptable for use in vapor degreasing operations. Stabilizing additives have specific gravities less than trichlorethylene and, therefore, lower the specific gravity of the mixture. Furthermore, it is entirely possible to have equally good and stable products, using various stabilizer systems, which will have different specific gravities. Specifying a narrow range for the specific gravity of a degreasing grade of trichlorethylene does not, therefore, guarantee or insure a superior product.

Much the same reasoning applies to the distillation range of the solvent. Since stabilizers have normal boiling points below and above trichlorethylene, they change its distillation range. A very narrow boiling range is not a necessary requirement for a good degreasing grade of trichlorethylene. What is important is a wide enough range to permit sufficient amounts of stibilizers to be added so that the solvent will perform satisfactorily in actual service.

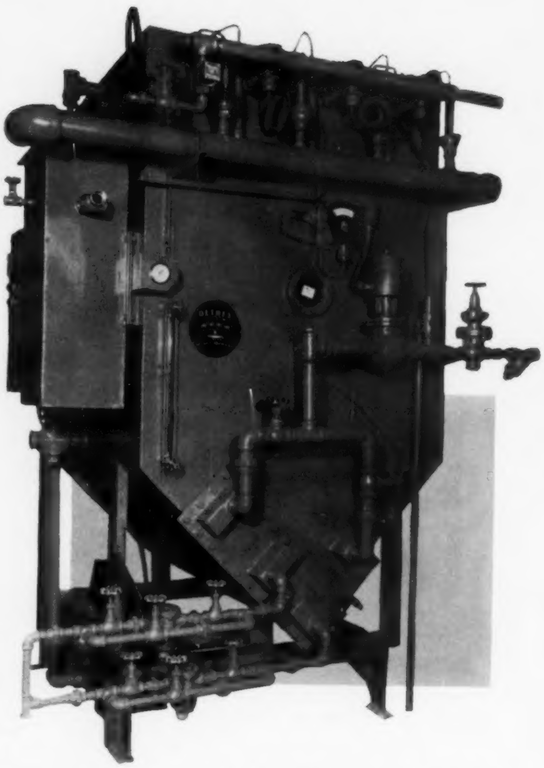


Fig. 2 – Still Removes Contaminants From Solvent and Permits Continuous Degreaser Operation. This model can distill up to 600 gal. of solvent an hr.

Table III – Comparison of Equipment and Operating Costs for Solvent Degreasing and Aqueous Washing*

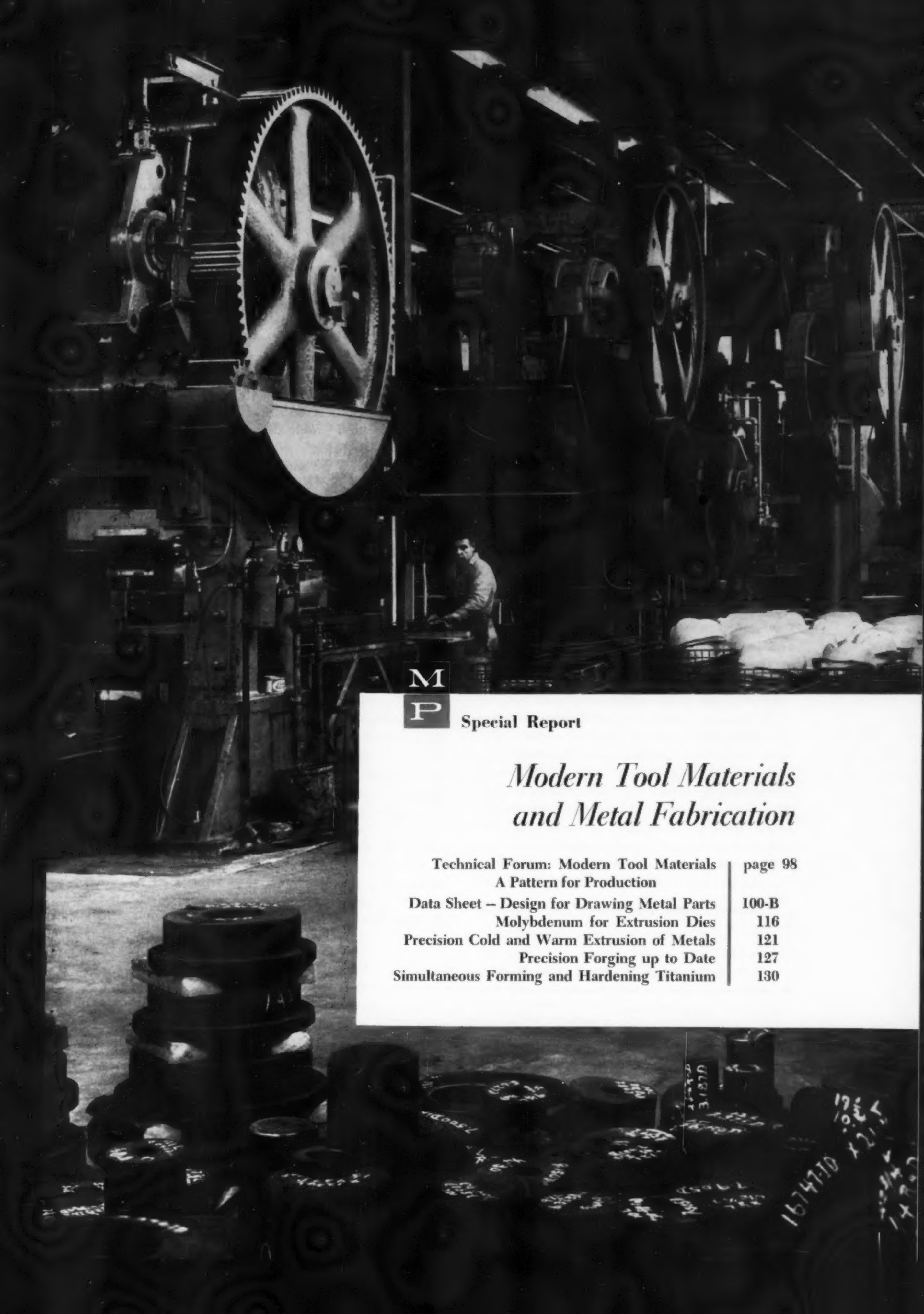
Item	Solvent Degreasing	Aqueous Washing
Equipment Costs		
Equipment	$12,283	$13,940
Installation	3,000	3,500
Plant space ($15 per sq.ft.)	6,076	6,720
Steam generating equipment ($5 per lb. per hr.)	4,850	18,300
Power equipment ($100 per kw.)	220	3,720
General facilities (5% of equipment value)	765	872
Total equipment costs	$27,193	$47,052
Hourly Operating Costs		
Solvent ($1.53 per gal.)	$3.75	$ —
Chemicals ($0.82 per gal.)	—	.79
Steam ($1.50 per 1000 lb.)	1.85	5.50
Electricity ($0.011 per kw.)	.02	.41
Water ($0.14 per 1000 gal.)	.18	.02
Hourly operating costs	$5.80	$6.72

*Based on cleaning automatic transmission parts at the rate of 40,000 lb. per hr. Conveyer speed, 18 ft. per min. Equipment: vapor-spray-vapor degreaser, monorail type, 45 × 9 ft.; monorail washer, wash-rinse-blowoff, 64 × 7 ft.

The two examples involving specification limits indicate the importance of knowing the relationship between the properties of a solvent and its performance in specific applications. Arbitrarily setting narrow limits for physical or chemical specification tests on cleaning solvents does not thereby insure better products. In some instances it may actually curtail solvent improvements. Judgment must be based on sound technology and a recognition of cleaning requirements as the criteria.

Obviously, no one physical or chemical test is specific enough to identify a degreasing solvent. A good specification, prepared cooperatively by producer and consumer, should include a sufficient number of physical, chemical and environmental tests, such as those given in Table II, with appropriate range of values for each so that, taken together, they do define a standard acceptable product.

Industrial clean- (*Continued on p.* 162)



MP

Special Report

Modern Tool Materials and Metal Fabrication

MP Technical Forum: Modern Tool Materials

A Pattern for Production

Air Hardening Toolsteels Offer Lower Costs, Improved Performance

*By J. Y. RIEDEL**

THE INCREASED USE of air hardening grades is an important trend in tool and die steels. This has come about largely because the air hardening toolsteels have proven themselves to the fabricator as a means of reducing tool costs and improving production. A number of new air hardening grades have been developed, which are available in warehouse stocks.

If a selection of various types of tools is made from air hardening toolsteels and compared in service with a group of similar tools made from steels which require liquid quenching for hardening, the air hardened tools will outperform the liquid quenched tools in service. This may not necessarily be obvious when individual tools are compared but will appear if a large number of tools are studied.

The reason air hardened tools outperform liquid quench tools (in a large statistical sample) can be summed up in one word – consistency. This factor is evidenced in many ways:

• **Dimensional Stability** – All tools, when hardened, develop small, but measurable dimensional changes (so-called distortion). Air hardened tools not only show less dimensional changes than liquid quenched tools, but the changes that occur are remarkably uniform tool to tool. By contrast, identical liquid hardened tools show considerable dimensional variation.

• **Hardness** – Duplicate air hardened tools invariably show the same hardness after heat treatment. Liquid quenched tools may show erratic hardness in various locations due to variations in effectiveness of the liquid quench, and duplicate tools may have a variable hardness pattern.

• **Residual Quenching Stresses** – All tools develop residual internal stresses due to the hardening operation. Liquid quenched tools develop high internal residual stresses because of the variation in cooling rate which occurs in different locations on a tool during the quench. These stresses, if improperly controlled, can lead to cracking of the tools during heat treatment or in grinding. They may also impair the load-carrying ability of the tool. By contrast, air hardened tools develop only a small amount of stress during hardening because of more uniform cooling. Furthermore, the degree of internal stress is uniform from tool to tool so that service performance of duplicate tools is reasonably consistent.

Although the purchase price of air hardening toolsteels is usually higher than that of oil or water hardening steels, cost of the finished tool is often lower. This is because less grinding

*Toolsteel Engineer, Bethlehem Steel Co., Bethlehem, Pa.

Table I – Types of Air Hardening Toolsteels

Type	A.I.S.I. Designation	C	Mn	Cr	Mo	W	V
Tool and die, general	A-2	1.00	0.60	5.00	1.00	—	0.30
Tool and die, free machining	A-4	0.95	2.00	2.20	1.10	(Pb added)	
Tool and die, high production	D-2	1.55	0.40	11.50	0.80	—	0.90
Shock resisting	—	0.50	0.70	3.25	1.40	—	—
Hot work	H-12	0.35	0.35	5.00	1.65	1.50	—
High speed	M-2	0.82	0.25	4.00	5.00	6.50	2.00

is necessary after heat treatment for finishing and fitting the air hardening tools into an assembly. Also, this increased reliability and the avoidance of heat treatment cracks may eliminate the need for duplicate tooling.

Air Hardening Steels Should Be Air Hardened

To realize the advantages of air hardening steels, it is essential that they actually be hardened by air quenching. It is possible to harden all air hardening steels by liquid quenching (oil quench or salt quench as in martempering) and this is frequently done because of the convenience of existing heat treatment equipment. However this is a serious mistake because it sacrifices almost all the basic advantages of air hardening steels. Liquid quenching not only increases distortion and internal stresses but may crack the tools.

Whenever air hardening steels are used for large tools with section and length of 6 in. or greater, it is usually necessary to oil quench in order to produce full hardness. Although the type of steel involved may be "air hardening", the application is actually one of a deep hardening, oil quenching steel. Obviously, the benefits of air hardening steels do not apply in such instances. On the other hand, such an application is metallurgically sound and should not be interpreted as misuse of such steels.

Today, tools for practically every purpose can be made from the air hardening grades. As shown in Table I they are available in shock resisting, hot work, and high speed types, as well as the so-called tool and die types.

A Pattern for Production

New Toolsteels for Abrasion Resistance and Exceptional Toughness

*By NEIL J. CULP and JOSEPH S. PENDLETON, Jr.**

IN RECENT YEARS, ONLY A FEW important new tool and die steels were developed because, with the standard compositions available, the metallurgist could select one with the hardenability, wear resistance or nondeforming properties needed for a specific application. If it's a simple tool, he can use a water hardening carbon toolsteel; if it's more complex, he'll probably use an oil or air hardening grade. Within each of these groups, he can find a standard alloy which will give him the wear resistance, or hardness, and the freedom from size change that he needs.

Swing Toward Air Hardening

Naturally, not all the desirable properties can be realized without some sacrifice in other factors. For example, the present trend is to much broader use of the air hardening steels. Their slightly higher cost is more than offset by eliminating the quenching operation. They are deep hardening and are relatively free from size change in heat treatment. The disadvantages are that these steels usually must be air cooled from comparatively high temperatures, 1750° F. or higher, and temperature control must be fairly precise.

The high quenching temperature is a problem since most of the oil and water hardening steels are quenched from temperatures below 1600° F. In many instances special furnaces are required when air hardening steels are used. An additional factor is that decarburization can occur quite rapidly at the higher temperatures, so that a controlled atmosphere furnace or neutral salt bath is needed.

If greater wear resistance, or higher hardness, is required, it can usually be obtained with steels containing more carbon and higher alloy content (such as chromium and tungsten). In such steels, however, both machinability and toughness are low, so they are not completely satisfactory for such applications as intricate embossing dies or long, comparatively thin punches where flexing occurs.

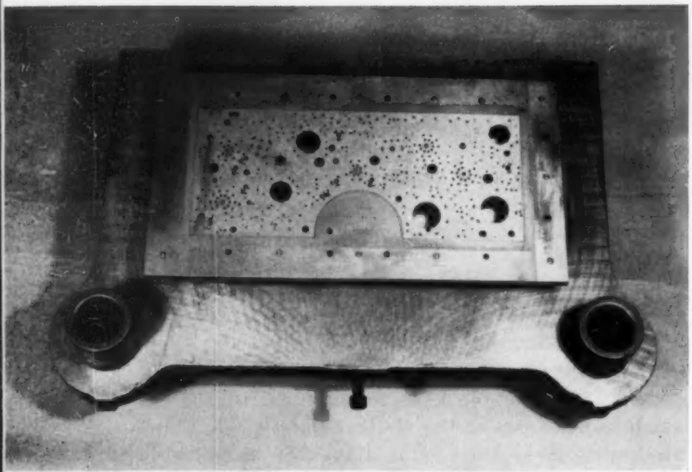
Objectives of Toolsteel Research

At Carpenter, our research on new tool and die steel compositions has been directed at alloys to meet the following requirements:

1. They should be air hardening because of the greater safety and freedom from size change.

2. The hardening (austenitizing) temperature should be below 1600° F. and the hardening temperature range should not be too narrow. The lower hardening temperatures are more economical, help reduce size change and also

*Assistant Manager of Research – Metallurgy, and Metallurgist – Tool and Alloy Steels, respectively, Carpenter Steel Co., Reading, Pa.



This Die, ⅞ In. Thick by 14½ In. Long, Was Machined From a Solid Piece of A.I.S.I. Type A-6 Made by Carpenter Steel Co. It contains 792 holes. The die is hardened at 1500° F., air cooled, and drawn at 350° F. for 6 hr. to obtain hardness of Rockwell C-60. After heat treatment the size change to the die section 14½ in. long was only 0.0025 in. over-all, or less than 0.00018 in. per in. The die is used in fabricating printed circuits

minimize the possibility of decarburization.

3. Alloy content should be low to keep the cost down and also because the lower alloy steels are usually easier to machine.

The first steel developed to these specifications has the trade name "Vega", and it is now accepted as an A.I.S.I. standard, Type A-6. It contains 0.70% C, 2.00% Mn, 0.30% Si, 1.00% Cr and 1.35% Mo. It is an air hardening grade and the recommended austenitizing range is 1525 to 1600° F. After tempering at 350° F., the size change is about 0.0003 in. per in. Machinability is good and, for a toolsteel, it is comparatively tough.

Two New Toolsteels

Patents have just been granted on two new steels which have advantages of simplified heat treatment. One has excellent wear resistance – better than that of the high-carbon, high-chromium steel, A.I.S.I. Type D-2. The other is a tough toolsteel which has notched-bar Izod impact values of 10 to 14 ft-lb. at hardnesses of Rockwell C-59 to 60. Neither of these steels is commercially available yet but both have undergone considerable field testing.

The wear resistant alloy contains 1.5% C, 2.0% Mn, 0.25% Si, 0.9% Cr, 1.0% Mo and 4.0% W. It can be air hardened from 1550 to 1600° F.; after drawing at 350° F., its hardness is Rockwell C-63 to 64. Size change in heat treatment averages about 0.0005 in. per in. on 1 in. rounds, 4 in. long. In field tests on punches and dies, where it was compared to high-carbon, high-chromium air hardening steel (Type D-2), its size change and warpage were perceptibly lower.

In a large number of applications, where the service life of this new wear resistant alloy was compared with that of Type D-2, the average improvement was about 100%. The tests included dies for cold extrusion of aluminum, blades for shearing S.A.E. 1010 strip, dies for coining nonferrous metals and for cold drawing S.A.E. 1020 bars.

Other tests showing improvements in service life were for brick molds used to form highly abrasive silica brick where the new alloy was 20% better than Type D-2. When used in punches with S.A.E. 1020 and phosphor bronze, service life between grinds was improved 15%. The best result was in a plunger for a die used to compact powdered metals which lasted four times longer than previous tools made from a standard high-carbon, high-chromium steel.

New Steel Has Exceptional Toughness

Our new steel for exceptional toughness contains 0.70% C, 0.50% Mn, 0.3% Si, 1.0% Cr, 1.0% Mo and 2.50% Cu. It can be air hardened from 1550 to 1600° F., and after drawing at 350° F., its hardness is Rockwell C-59 to 60. Size change during heat treatment is about 0.0003 in. per in.

Applications for this alloy are in tools and dies that fail by fracture rather than wear. One example is the blades and blade inserts used to shear steel plate up to 1 in. thick. In an automotive plant where the new alloy was tested for this application, blades lasted five times longer than any toolsteel previously tested. Similar improvements in service life, although not as great, have been found for embossing dies for jewelry and in coining dies for parts on which no flash can be tolerated. Design of the latter type die creates high radial stresses in service that cause early brittle failures. The added toughness of the new steel apparently is sufficient to absorb these high stresses longer than other die steels previously used.

Fatigue is also important in punches used for

Why metals corrode...and how you can prevent it

The basic cause of corrosion is the instability of metals in their refined state. Metals tend to revert to their natural states through the processes of corrosion. For example, when you analyze rust, you will find it is iron oxide. When you analyze natural iron ore, you find it, too, is iron oxide. Six forms of corrosion which can attack the equipment you design are:

1. General tarnishing or rusting with occasional perforations in highly affected areas.

2. Highly localized attack by pitting.

3. Cracking induced by a combination of stress and corrosion.

4. Corrosion confined to crevices, under gaskets, or washers, or in sockets.

5. Corrosion of one of an alloy's constituents leaving a weak residue.

6. Corrosion near the junction of two different metals.

In all of the six forms of corrosion mentioned above, corrosion has the same basic mechanism. It's similar to the electrochemical action in a dry cell.

The electrolyte in the dry cell corresponds to the corrosive media, which may be anything from the moisture in the air to the strongest alkali or acid.

The plates of the battery correspond to the metal involved in corrosion.

A potential difference between these metals or different areas on the same metal causes electricity to flow between them through the electrolyte and a metallic bridge or contact that completes the circuit.

At the anode, a destructive alteration or eating away of metal occurs when the positively charged atoms of metal detach from the solid surface and enter the solution as ions.

The corresponding negative charges, in the form of electrons, travel through the metal, through the metallic bridge, to the cathode.

Briefly then, for corrosion to occur, there must first be a difference in potential between the metals or areas on the same piece of metal so that electricity will flow between them. Next, a release of electrons at the anode and a formation of metal ions through disintegration of metal at the anode. At the cathode, there must be a simultaneous acceptance of electrons. Action at the anode cannot go on alone, nor can action at the cathode.

CONTROLLING CORROSION

When corrosion occurs because of the differences in electrical potential of dissimilar metals, it is known as galvanic action. Differences in potential from point to point on a single metal surface causes corrosion known as local action.

When you plan against galvanic corrosion it is essential to know which metal in the couple will suffer accelerated corrosion . . . will act as the anode in the corrosion reaction.

The galvanic series table shown below can supply this information. In any couple, the metal near the top of this series will be the anode and suffer accelerated corrosion in a galvanic couple. The one nearer the bottom will be the cathode and remain free from attack or may corrode at a much slower rate.

GALVANIC SERIES TABLE

Magnesium
Magnesium alloys
•
Zinc
•
Aluminum 25
•
Cadmium
•
Aluminum 17ST
•
Steel or Iron, Cast Iron
•
Chromium-iron (active)
•
Ni-Resist
•
18-8 Stainless (active)
18-8-3 Stainless (active)
•
Lead-tin solders
Lead, Tin
•
Nickel (active)
Inconel (active)
•
Brasses, Copper, Bronzes
Copper-nickel alloys, Monel
•
Silver solder
•
Nickel (passive)
Inconel (passive)
•
Chromium-iron (passive)
18-8 Stainless (passive)
18-8-3 Stainless (passive)
•
Silver
•
Graphite, Gold, Platinum

HOW TO USE THE CHART

Notice how the metals are grouped in the galvanic series table. Any metal in one group can be safely used with any other metal in the same group. However, when you start mixing metals from different groups, you may run into serious galvanic corrosion of the metal higher on the list. And the further apart these metals are listed, the worse this corrosion may be.

But, if you have to mix metals, pay particular attention to the electrical contact between them. Eliminate any metallic bridges or contacts of metal to metal that will permit the flow of electrons through them. You can do this by separating the metals physically, or by using insulation or protective coatings. Another factor is the relative areas of the metals in contact with each other. Parts having the smaller area should be of a metal with a lower listing on the galvanic series table than the metal used for the larger area.

When you plan against local action, remember that the corrosion process is galvanic: Electrons move from one point in the metal to another. One of the easiest ways to prevent local action is to use a metal with little or no impurity. When alloys are involved, make sure the constituents are closely listed in the galvanic series table. Local action may also be stopped by the use of protective coatings, which shield the metal from the corrosive media. Environment must also be considered, for its nature may be an important factor in either promoting or restricting corrosion.

TECHNICAL ASSISTANCE

As you can see, many factors are involved in both local and galvanic action. That's why it's best to bring your metal problem to Inco's Corrosion Engineering Service. Available data will be furnished wherever possible . . . tests will be made where needed. Inco's Corrosion Engineering Service will be glad to apply principles of corrosion control to your specific problem.

LITERATURE

The publications listed below will provide more detailed information on how you can combat corrosion by using nickel-containing metals.

Publication Number	Name
A232	Corrosion Problems in Nuclear Reactor Power Stations
A59	Factors of Importance in the Atmospheric Corrosion Testing of Low-Alloy Steels
A62	A Theory of the Mechanism of Rusting of Low-Alloy Steel in the Atmosphere
A137	Corrosion by Some Organic Acids and Related Compounds
A144	Some Observations of the Potentials of Stainless Steels in Flowing Sea Water

A complete list of the 187 Inco publications and technical bulletins on nickel-containing metals can be obtained by writing for "List A", to:

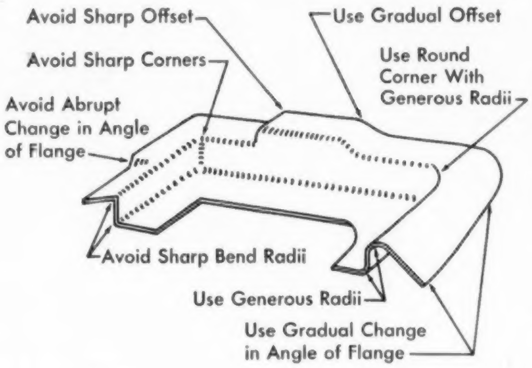
*Registered trademark

The INTERNATIONAL NICKEL COMPANY, Inc.
67 Wall Street New York 5, N.Y.

Circle 1776 on Page 48-A

Design Characteristics in Drawing Metal Parts*

General Principles



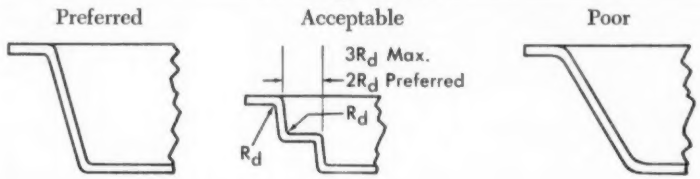
Recommended Reduction Between Annealings

Material	Reduction*
Steel	20%
Stainless	15–20
Aluminum	20–30
Copper	15–20
Brass	20–25
Zinc	10–15

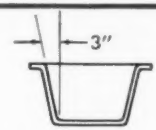
$$\text{*\% reduction} = \frac{D - O}{D}$$

where
D is predrawn shell diameter
O is redrawn shell diameter

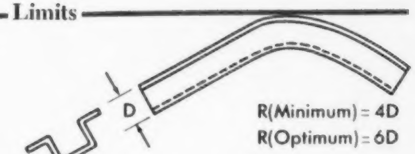
Forming Methods



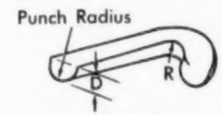
Limits

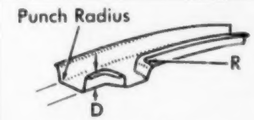


Draft (Drop Hammer) for 90° Sides



Contour





Alloy	With Punch Radius Equal to One-Half Part Depth or More		With Punch Radius Less Than One-Fourth Part Depth	
	Drop Hammer	Double-Action Press	Drop Hammer	Double-Action Press
3003-0	0.6 D	0.4 D	0.75 D	0.6 D
2024-0, 5052-0, 7075-0, 6061-W, 70-78-W	0.8 D	0.65 D	0.9 D	0.8 D
Stainless steel (annealed) Low-carbon steel	0.5 D	0.35 D	0.65 D	0.5 D

Common Drawing Defects

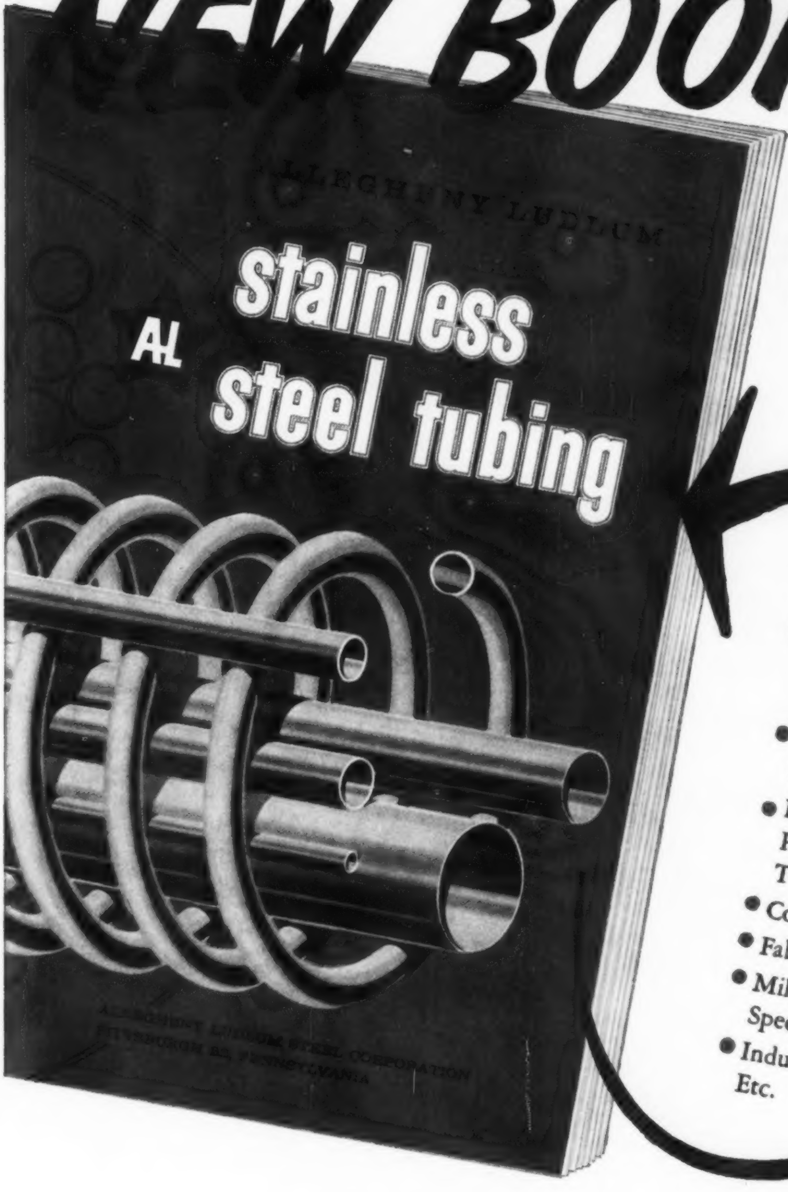
Defects and Characteristics	Causes
Flange Wrinkles – Radial ridges on shell flange	Insufficient pressure on blank holder, excess lubrication, die and blank faces not parallel
Wall Wrinkles – Vertical ridges on sidewall	Insufficient pressure on blank holder
Puckers – Ripples on the wall running down from flange	Insufficient pressure on blank holder
Step Rings – Depressions on sidewalls of shells	Level radii are too sharp, redraw die radius too sharp
Draw Marks – Vertical score lines on outside of shell	Rough draw surface, inadequate lubrication, dirt or foreign matter

Defects and Characteristics	Causes
Orange Peel – Rough or open appearance on sidewall or at corner of shell	Excessive pressure on blank holder; insufficient cold working
Miss Strike – Uneven shell height or flange width	Incorrect tool setting, misalignment of punch or blank, blank skidding due to uneven pressure
Earing – High points on top of shell	Worn die on blank holder causing pinch; poor physical properties of metal
Burnished Spots – Wide burnished areas on shell wall	Insufficient clearance
Fractures – Defects appearing in corners of shell	Excessive pressure, radii too small or too sharp, insufficient clearance

Adapted From A.R.D.C. Production Design Handbook

NEW BOOKLET

on STAINLESS STEEL TUBING sent on request



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- Stainless Steel grades
- Product data on Seamless Tubing and Welded Tubing
- Size range Stainless Pipe & Tubing
- Design data—Internal Pressures—Elevated Temperatures, etc.
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- Fabrication data
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1287

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Write for your free copy of Allegheny Stainless Steel Tubing, *Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pennsylvania. Address Dept. MP-5.*

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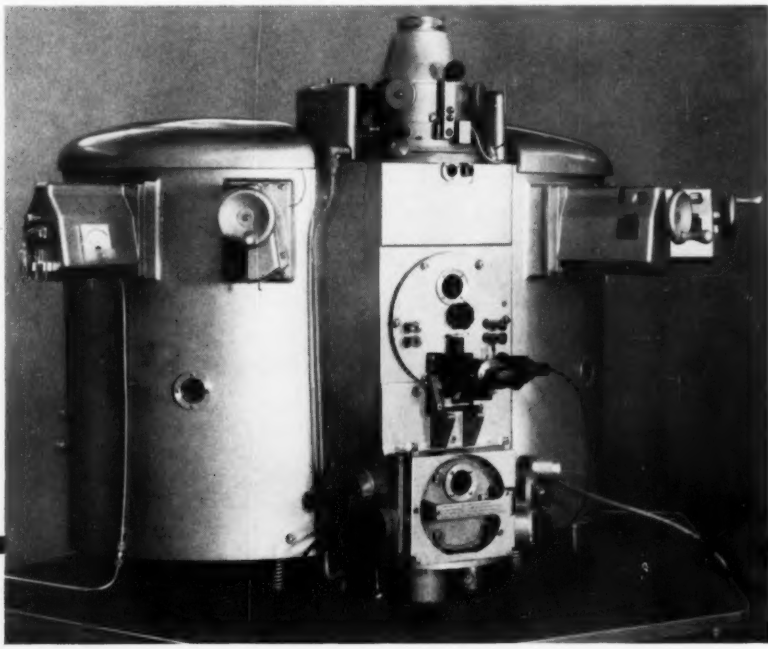

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cold extrusion of steel and in similar punches used for some deep drawing or deep dimpling operations, where flexing can occur. Again, in such applications, this new tough steel has proven superior.

A Pattern for Production

Larger Tooling Will Focus Attention on Quality to Minimize Defects

*By P. R. BORNEMAN**

A MAJOR TREND IS IN THE AREA of larger-size tooling. This is particularly evident in applications for hot work steels where large die castings are requiring larger and larger dies. Likewise, as larger extrusion presses are designed, tooling requires hot work steels for bigger dies. This increase in size of dies demands not only larger and more versatile production equipment for their fabrication, but also places more emphasis upon quality, since large-size tooling increases the possibility of defects occurring in an individual piece.

This increased emphasis upon quality will require that more attention be given to vacuum melting and treating processes for tool materials. These processes now offer improvements where excellence of surface finish is of major importance, such as in work rolls for cold finishing. It is also anticipated that vacuum melting will improve punch and die tool materials where fatigue failure causes premature breakage.

In cutting tools, emphasis is being placed upon the application of high speed steels of the more highly alloyed types for difficult machining operations encountered in the fabrication of high-temperature alloys. In the "super" high speed steel field also, the trend is toward replacement of tungsten-base high speed steels with molybdenum-base materials.

*Chief Research Metallurgist, Tool and Die Steels, Allegheny Ludlum Steel Corp., Pittsburgh.

Recently, a special cutting tool material was developed for fabrication of unground circular tools. It is substantially free from any non-uniformity of growth or contraction around the circumference during heat treatment.

Special Properties Receive More Attention

Increased emphasis on long production runs with cold work die steels (to meet competition from abroad) will see more attention given to highly abrasion resistant die steels. Deep drawing of the more exotic materials used for aircraft and missiles will also require die materials which resist both wear and galling. Although fabrication of this type of die has proved difficult in the past, new techniques have been developed which make its use economically attractive and in many cases a necessity.

It is expected that more of the 5% chromium air hardening steels will be used in cold work die applications. The size stability and other advantages inherent in these grades are widening their uses.

The 7178 Aluminum Extrusion Emerging From This 1200-Ton Hydraulic Press at Harvey Aluminum Measures Over 28 In. Wide. The increase in size of dies for large extrusions puts more emphasis upon quality of hot work steels since the possibility of defects occurring is increased with larger-size tooling. Vacuum processing is being adopted to improve quality of die steels

A Pattern for Production

A New Air Hardening, Graphitic-Type Tool and Die Steel

*By D. J. GIRARDI**

THE POPULARITY OF GRAPHITIC-TYPE toolsteels has been steadily increasing. They give exceptional performance and their attractive processing characteristics have lowered tool and die production costs. "Graph-Air"† is a new toolsteel of this type which combines the desirable properties due to the presence of graphite with the advantages of air hardening, such as easier processing and greater dimensional stability.

Graphite gives toolsteels unusual properties. It acts as a chip breaker and dry lubricant during machining. During hardening, it acts as a stress-relieving medium. The static coefficient of friction of a graphitic-type toolsteel is about 50% lower than that of conventional toolsteels. Also, graphite reduces the modulus of elasticity – important for improved wear resistance. More elastic straining of the wear surfaces can occur before tearing takes place. "Graph-Air" contains 0.2 to 0.6% graphite after cooling from hot working or annealing; the graphite in the steel is exceptionally stable during further reheating or hardening.

Procedures for Hardening

Our graphitic toolsteel can be hardened to Rockwell C-60 in still air, at the center of a 6-in. round. Larger sections can be hardened if agitated air cooling, or partial oil quenching to black heat followed by air cooling, is used. Also, large sections can be satisfactorily air hardened from 1700° F., if this is followed by tempering at high temperature. However, this is not recommended because of the added chance of scaling and decarburization.

"Graph-Air" can be heat treated in the same salt baths and furnaces as the standard water hardening and oil hardening toolsteels. Treatment in the range 1450 to 1500° F. gives hardnesses of Rockwell C-59 to 62 in 1 to 6-in. round sections. The lower hardnesses are obtained with the larger sections.

Under normal conditions the aggregate hardness of the material is about two Rockwell C units lower than the actual hardness of the martensitic matrix. This lower aggregate hardness stems from the inability of the Rockwell brale to miss the numerous graphite pockets in the steel.

Recommended hardening procedures are as follows: For cross sections up to 2 in. thick, the tool is heated to 1450° F. and held at temperature for 1 hr. plus 30 min. per in. of thickness or outside diameter. The same procedure is followed for larger sections, with heating to 1475° F. for 2 to 4-in. thick sections and 1500° F. for sections thicker than 4 in. Then it is cooled in air to room temperature. It is important that room temperature be reached before tempering; otherwise unsatisfactory hardness will result.

A good practice is to air cool until the piece can be handled with bare hands and then cool it in water before tempering. Temper is required to hold size, hardness and maximum impact strength. Effects of tempering temperature on hardness are shown in Fig. 1. Preheating before hardening isn't necessary but is considered good practice. Protection against excessive decarburization is recommended.

Dimensional Stability Is Good

Characteristic dimensional changes that occur during air hardening and tempering are shown in Fig. 2. The magnitude of the dimensional changes during still air hardening and tempering is exceptionally small and essentially equal in the longitudinal and transverse directions. These changes are at least as small as for the D-2 type steel (1.5% C; 12% Cr; 1% Mo) which is considered to be excellent in this respect.

Cold treating after hardening is commonly used to obtain long-time dimensional stability. However, the retained austenite is strongly stabilized in the hardening and tempering operations, so cold treating is actually not

*Manager, Metallurgical Research and Process Control, Timken Roller Bearing Co., Canton, Ohio.

†Registered trade-mark, Timken Roller Bearing Co. A typical analysis for "Graph-Air" is: 1.35 C; 1.85 Mn; 0.025 P max.; 0.025 S max.; 1.20 Si; 1.85 Ni; 1.50 Mo.

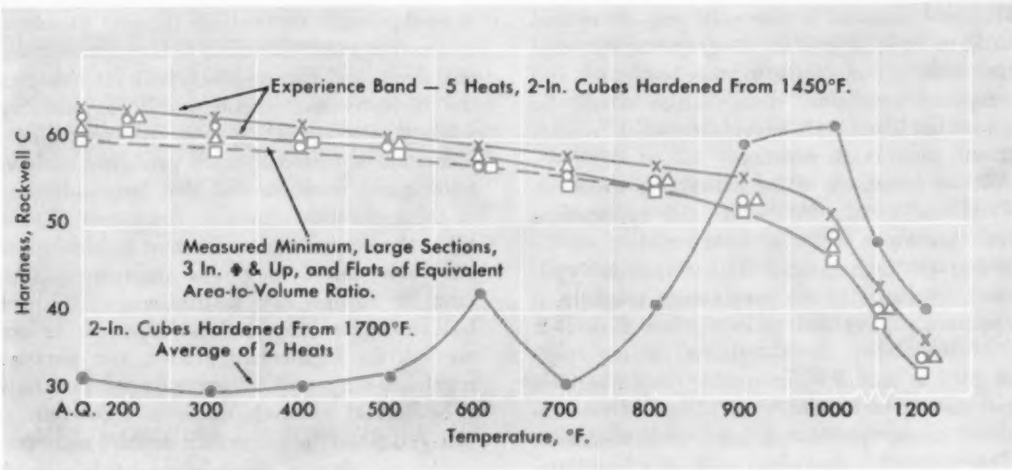


Fig. 1 – How Tempering Temperature Affects Hardness of Graphitic-Type (Graph-Air) Toolsteel

needed. When long-time dimensional stability is required, cold treating after tempering is recommended as an added precaution. This treatment assures stability without incurring the large dimensional changes that would arise from deep freezing directly after hardening.

Toughness of "Graph-Air", as measured by unnotched Izod impact, is comparable with results for A-2 and D-2 high-chromium air hardening steels. The elastic modulus of the

Fig. 2 – Dimensional Changes in Graphitic Type (Graph-Air) Toolsteel During Tempering. Curves in top chart are based on specimens hardened from 1450° F. Specimens for bottom chart (note increased scale) were hardened from 1700° F.

annealed material is 28.5×10^6 psi., compared to 32 to 34×10^6 psi. for nongraphitic annealed toolsteels. For steels in the hardened and tempered condition, these values would be somewhat lower. However, they would remain in the same relative order.

Wear resistance of the material is excellent. Field test results in various die applications have shown it to be as wear resistant as the D-2 type high-carbon, high-chromium toolsteel. Because of the presence of graphite, it apparently galls and picks up less than D-2.

Machinability of "Graph-Air" is not quite as good as that of oil hardening graphitic steels but compares favorably with that of conventional nongraphitic oil hardening toolsteels. The material is less sensitive to grinding damage than conventional oil hardening grades. The presence of graphite prevents any rapid buildup of surface stresses during grinding and thus inhibits crack formation. Wet grinding is recommended where possible. The tool material is readily welded.

A Pattern for Production

Fundamental Studies Provide New Tool Materials for Many Areas of Metalworking

*By JOHN C. HAMAKER, JR.**

Studies of fundamental properties and microstructures of toolsteels during the past 15 years have provided background for the development of new tool and die materials and improvements in their manufacture. By correlating data on bend, impact, abrasion, microhardness and hot hardness tests, with manufacture, heat treatment, carbide and matrix characteristics of the steel, existing grades have been improved and promising areas for future development have been delineated.

This approach is illustrated by rapid progress in high-carbon, high-vanadium steels for super wear resistance which are now appearing in many grades. In 1939, J. P. Gill disclosed in several patents† that definite ratios of vanadium and carbon could be added to high speed steels, die steels, and carbon steels without changing the heat treating characteristics appreciably, while greatly increasing wear resistance due to formation of extremely hard vanadium carbide. Subsequent work showed that large additions of these elements – even to the extent of doubling the normal carbon content in high speed steel – decreased toughness surprisingly little (due to fineness and distribution of the carbides), while hot hardness equaled, or exceeded, the high-cobalt grades, and abrasion resistance surpassed all wrought tool materials.

Additional research under a fellowship at M.I.T. defined the phase relationships more precisely and showed the relative insolubility of this carbide at hardening temperatures. Microhardness studies revealed a carbide hardness equal to tungsten carbide.

"Super" Wear Resisting Steels

A flurry of high-carbon, high-vanadium tool and die steels have since been introduced. Some time ago H-13 was added to the series of 5% chromium hot work die steels by raising the vanadium content from 0.50% to 1.00%, based on a research report showing improved hot hardness at 1.0 and 1.5% vanadium. More recently, hot work steels with still higher vanadium content have appeared for forging jet blades and similar high-abrasion applications.

Several high-carbon high-vanadium cold work die steels are now commercially produced for brick mold liners and extremely long run die applications. The high-vanadium, "super" high speed steels are among the most popular cutting tool materials, particularly suited to the new difficult-to-machine heat resisting alloys which require high positive rake angles for minimum work hardening.

Fundamental Studies Are Important

Other examples might be cited in which data on basic microstructures and properties are resulting in new or improved tool materials. Among these are a family of Matrix Steels‡, based on fundamental phase studies, for special tooling applications. Vacuum melting is opening a whole new family of tool materials using compositions heretofore unavailable by

*Director of Research and Metallurgical Engineering, Vanadium-Alloys Steel Co., Latrobe, Pa.

†U.S. Patent No. 2,174,281; 2,174,282; 2,174,283; 2,174,284; 2,174,285; and 2,174,286.

‡Registered trade-mark, Vanadium-Alloys Steel Co., Latrobe, Pa. Patent applied for.

air melting. Powder metallurgy contains still other broad areas yet unexplored.

The future will see increased use of metallurgical relationships in the design of new tool materials for special applications, replacing the "rule-of-thumb" alloying methods.

A Pattern for Production

Air Hardening Grade And Vacuum Degassed Offer New Possibilities

*By CHARLES T. EVANS, JR.**

WE ARE APPROACHING the tool cost problem of the metal fabricator from several standpoints. An important issue is quality control where statistical inspection is used to insure satisfactory tool life. Also, new processing techniques are getting a lot of attention in the belief that much can be done without departing from the commonly used toolsteel grades.

An example of processing improvement is our recent introduction of vacuum degassed H-13 (Thermold AV) toolsteel. This is of interest to the aluminum die-casting industry which is producing larger and heavier castings, in parts such as automotive transmission housings, outboard motor shrouds, and power lawnmower covers. These large die castings have created a requirement for extremely large sections of sound quality toolsteels because many die cavities are machined from solid blocks weighing as much as 10,000 lb. We are now vacuum degassing all die steels destined for these large sizes to insure freedom from gaseous impurities which might cause failure in service.

Air Hardening at Low Temperature

We have recently introduced a low-temperature air hardening toolsteel, A.I.S.I. Type A-6 (Lo-Air). This grade combines the ease of machinability and the low-temperature heat treatment characteristics of oil hardening toolsteels, with freedom from cracking and deformation in heat treatment, typical of the air hardening types. Consumer acceptance leads us to believe that this development will help to shorten the time when air hardening toolsteels become the standard product for dies rather than the oil hardening types. The latter have, after many years, almost completely replaced straight carbon, water hardening steels for dies.

Over the years, particularly since World War II, molybdenum high speed steels have almost completely replaced tungsten high speed in perishable cutting tools. There are now only a few large users of high speed steel who are not able to routinely harden the molybdenum grades to get optimum cutting properties, whereas during the early days of the molybdenum types, heat treatment was a problem due to lack of familiarity in handling them.

The cutting tool industry is now beginning to apply even more recent developments in molybdenum high speed steels, such as M-7 (Motung CV) and M-33 (Super Motung Extra). The

*Vice-President, Technology and Development, Universal-Cyclops Steel Corp., Bridgeville, Pa.

Trend Toward Larger Automotive Die Casting From Aluminum Is Requiring Large Sections of Toolsteels Which Are Vacuum Degassed to Insure Sound Quality. Many die cavities are machined from solid blocks weighing as much as 10,000 lb. (Courtesy Doehler-Jarvis Div., National Lead Co.)

unusually high carbon and high vanadium contents, typical of M-7 and similar newer molybdenum grades, provide extreme abrasion resistance and cutting ability. The M-33 type of high speed steel is another example of combining maximum hardness and abrasion resistance with good toughness. It probably represents the best combination of toughness and abrasion resistance obtainable in what might be called the "super high speed" steels. Also important is its relatively low cost.

Die Materials Based on Molybdenum

One very promising area for development of new tool materials is the refractory metals. Considerable success has been realized with an alloy of molybdenum plus 0.5% titanium in both die-casting dies for zinc and aluminum and in the hot extrusion process for steel.

The advantages of molybdenum in hot work applications are its extremely high resistance to heat checking, wash and erosion at elevated temperatures. At the present time, high hardness, usually associated with hot work toolsteels, cannot be secured with molybdenum-base alloys. But even at low hardnesses, many costly hours of extrusion press or die-casting machine downtime can be saved by the proper application of this metal.

Research on molybdenum, as well as tungsten, columbium, and other refractory alloys, is expected to continue at a high rate. This effort will be aided substantially by the completion of our inert fabrication facility ("In-Fab") where refractory metals can be hot forged and rolled at temperatures upward of 3000° in an atmosphere of inert gas.

A Pattern for Production

Aluminum Oxide Tools Permit High Speed Machining

*By R. J. DORR**

STUDY OF THE USE of aluminum oxide for cutting tools began in Germany at the turn of the century and since then has been pursued in Europe, Russia and the United States.

*Manager, Advance Product Engineering, General Electric Co., Detroit.

In June 1955, Bennett Bovarnik and Wallace B. Kennedy of the Rodman Laboratory, Watertown Arsenal, published the results of their investigation on machining steel with ceramic tools. It was concluded that metal could be machined with aluminum oxide cutting edges at speeds higher than could be employed with cemented carbide tools in use at that time.

Industry wanted to know more about higher speed machining, longer tool life, and the possibility of improving economics.

One company producing cast iron brake drums converted to oxides after obtaining the following results in extensive tests:

	CARBIDE	OXIDE
Speed	467 fpm.	875 fpm.
Feed	0.016 per rev.	0.015 per rev.
Depth of cut	0.022 in.	0.022 in.
Tool life per corner	20 pieces	75 pieces
Cutting time per piece	45 sec.	27 sec.

Another company converted to oxides for turning A.I.S.I. 1050 lathe spindles after obtaining a 50% increase in production due to higher speeds.

Results such as these proclaimed the beginning of a new era in cutting metals. However, higher cutting speeds showed up the need for better machine tools and for fixturing with improved rigidity, greater horsepower and finer balance. Equipment makers responded with experimental lathes which would operate up to 18,000 sfm.; a finish of 30 rms. on 1045 steel could be maintained using oxide tooling.

Use of Existing Equipment

The philosophy of extending the range of machining with carbides to higher speeds through the use of oxide tooling had been established. What remained to be done before moving on in this direction was the development and installation of new machine tools and fixtures. The laboratories had provided the tool materials, but machine tool development (which we must remember is predicated to some extent on a visible customer need) lagged behind. Thus, engineers interested in using oxides began to direct their attention toward available equipment and current jobs to gain productivity.

Many of these applications overlap into areas where cemented carbides are employed. For example, a manufacturer of Meehanite iron cylinder liners used a WC-Co grade for both the rough and finish turning operations. The time required to machine a casting with 19 in. O.D. and hardness of Brinell 240 was 3 hr.

This two-step machining operation is now being done in one step, using oxide cutting tips and time has been reduced to 1 hr.

A Detroit manufacturer reduced his cost 80% in finishing a steel shaft because oxide tools eliminated the need for a final grinding operation. Another important use for oxide tooling is in machining hardened steel parts (up to Rockwell C-62) where the normal machining method is grinding.

Further work on cutting tool materials based on aluminum oxide is expected to improve toughness of tools and thus allow still further penetration into the carbide application area. Future improvements in oxide tool materials for the even higher speed machining will come with the successful bonding of higher melting oxides, or combinations of oxides, such as beryllium oxide, zirconium oxide and thorium oxide and through a better understanding of the mechanism of tool failure.

A Pattern for Production

New Hot Work Die Steel Has Improved Heat and Abrasion Resistance

*By WILLIAM WILSON**

To meet the need for a superior hot work steel, A. Finkl and Sons Co. developed "Shellex" – a new hot work die steel of the 3.5% Cr-Mo-V type.

Experience has shown that the analysis combines greater heat and abrasion resistance than that found in many other more highly alloyed steels. It has unusually high hardenability and high hardness with toughness. The quality of this new steel is further improved by vacuum degassing in the ladle, reducing the hydrogen and oxygen content to make the steel tougher and cleaner.

Laboratory tests and experience from the field show that the hot work steel is a good material for extrusion rams, liners and supporting tools. Other applications include dies for forging and die casting.

Table I – Properties of Hot Work Die Steel

	Longitudinal Tests		Transverse
	80° F.	900° F.	80° F.
Tensile strength, psi.	225,000	172,000	223,000
0.2% yield strength	198,000	148,000	195,000
Elongation in 2 in.	5.3%	11.2	3.7
Reduction of area	8.0%	23.6	5.7

Both the high hardness and the greater heat resistance of the new hot work die steel are shown by the following tempering response after air hardening from 1850° F.:

Tempering Temperature	Brinell Hardness
Air hardened	601
1000° F.	578
1050	545
1100	495
1150	444
1200	331
1250	302

The high hardenability of "Shellex" permits air hardening of massive sections. For example, a 14-in. diameter section had a hardness of Brinell 461 across after air hardening from 1850° F. and tempering at 1000° F. and 1070° F. Tensile tests from the above round exhibited properties shown in Table I.

*Director of Research and Development, A. Finkl & Sons Co., Chicago.

A Pattern for Production

Die Steel for Plastic Molds and Die Castings Has Higher Hardenability

*By M. J. DEMPSEY**

Advances on a broad technical front in the toolsteel industry are providing improved materials at the fastest rate in history. Refinements in melting and casting techniques have led the way. We look for increased use of vacuum melting as a means of improving the quality and extending the usefulness of toolsteels. Vacuum induction melting and con-

*Manager, Customer Technical Services, Toolsteel, Crucible Steel Co. of America, Pittsburgh.

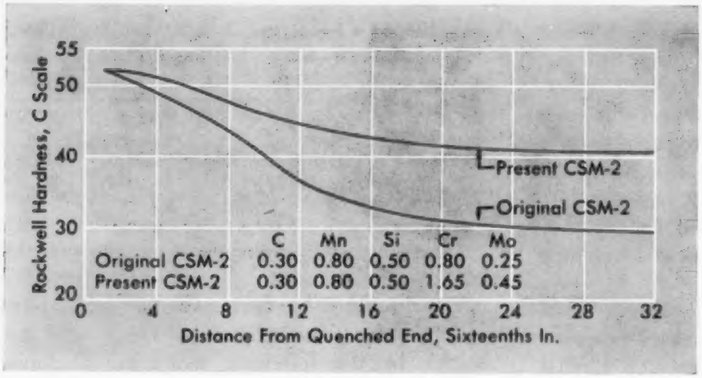
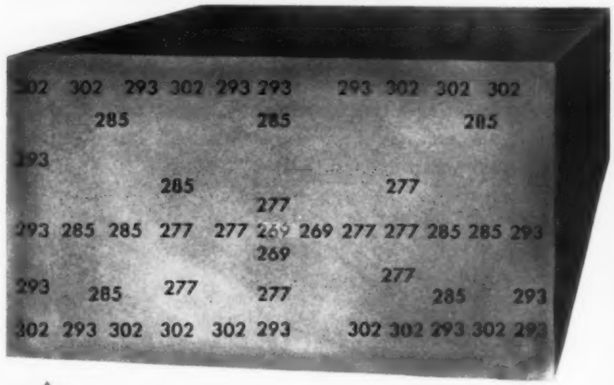


Fig. 1 – Hardenability of Original CSM-2 Compared With Modified CSM-2 Using Standard Jominy End-Quenched Hardenability Specimens

Fig. 2 – Hardness Pattern of Cross Sectional Slice From Block of Modified CSM-2, 20 In. Wide by 10 In. Thick, Heat Treated to Brinell 300



sumable electrode melting will continue to be important, while the application of vacuum degassing to the production of toolsteels will undergo critical examination in the months just ahead.

Some recent developments in tool materials at Crucible which hold significance for the metalworking industries are discussed below:

High Speed Steel – Dimensional stability has been built into Rex M 2 S used by hob manufacturers for accurate unground hobs. This factor helps to control variation in lead – so important to the hob maker. Proper balancing of composition has achieved maximum hardness, while free machining additives have insured finishability needed in "backed-off" cutters.

Plastic Mold and Die-Casting Die Steel – The composition of CSM-2 has been modified to give it higher hardenability. The curves in Fig. 1 give the hardenability of new material compared with the original. Figure 2 shows the hardness pattern of a thick block of modified CSM-2 heat treated to Brinell 300.

The higher hardness now obtained in the center of blocks up to 15 in. thick means longer die life. This steel may also be machined easily at Brinell 300 and it can be carburized safely in a single heat treatment.

Shock Resisting Toolsteel – LaBelle HT, our toughest toolsteel, came of age during 1959. It is an outgrowth of our extensive research into the silicon-manganese steels. Its composition is 0.43 C, 1.35 Mn, 2.25 Si, 1.35 Cr, 0.40 Mo, and 0.30 V. At the commonly recommended hardness of Rockwell C-54 to 56, this toolsteel has a V-notch Charpy impact strength of 15 to 16 ft-lb. Such high toughness allows the tool designer a far greater factor of safety where tools are subject to impact stresses.

A Pattern for Production

Throw-Away Inserts With Carbide Elements Offer New Concept of Economy

*By DENNIS G. JONES**

THIRTY YEARS AGO the expressions "cemented carbide" and "throw-away" inserts would have been as incompatible as profit and loss. Today, they are combined to produce profits. In fact, the change is even more phenomenal than might have ever been imagined because cemented carbides are now being used for mechanical elements as well as for cutting tools.

It has been demonstrated, for instance, that a solid carbide boring bar, utilizing "throw-away" inserts, can amortize itself in less than a year just through time saved. The resulting higher quality piece and less scrap are added

*Assistant Chief Engineer, Kennametal, Inc., Latrobe, Pa.

benefits. The full impact of these concepts has not yet been realized.

The throw-away carbide, indexable cutting insert was quickly accepted. The elimination of expensive diamond wheel regrinding, with its inherent control problems, was a welcomed change. The availability of a wide variety of inserts that could perform almost any common turning, boring or facing operation with high precision was immediately recognized as a basic tooling improvement.

Wasting Dollars to Save Pennies

Unfortunately, however, the biggest benefit of all was slow to be recognized. Strangely enough, the concept of "economical tool life" is more than half a century old. F. W. Taylor, the father of the science of metal-cutting, stated in his treatise on the subject in 1906 that ". . . the man who boasts of having run a tool without regrinding, say for longer than one and one-half hours on ordinary shop work, is merely boasting of how little he knows about the art of cutting metal cheaply".

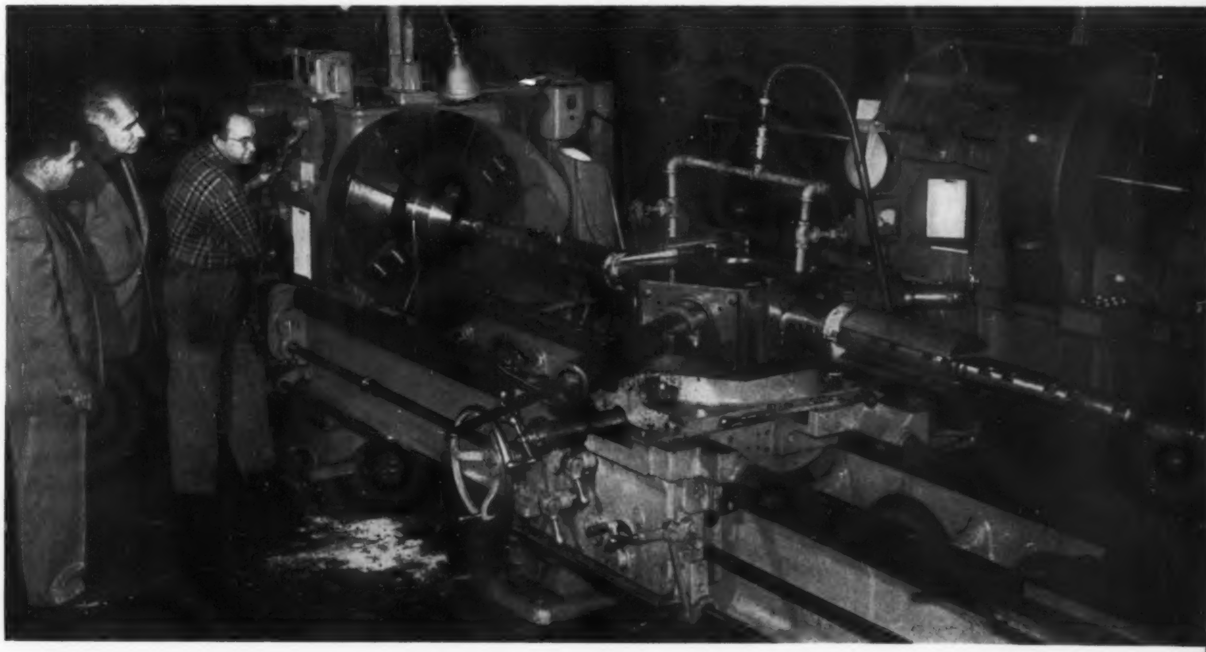
Although Taylor's work was done with high speed steel tools, it is just as true with carbide tools today – the man who boasts of long tool life is often "wasting dollars to save pennies".

The average metal cutting operation costs about \$8.00 per hr., or \$64.00 for man and machine for 8 hr., plus tool cost. If, in a hypothetical situation (many real ones can readily be found), 100 pieces are produced in 8 hr., the cost is \$64.00 plus \$2.00 for tools and the net cost is \$0.66 per piece.

If the operating conditions are changed to permit production of 200 pieces per shift, there obviously will be an increase in tool cost. It may even be substantial, perhaps four times as much. This would mean \$8.00 tool cost for 200 pieces, plus the constant \$8.00 per hr., \$64.00 per shift, man and machine cost or a total of \$72.00 per 200 pieces. The savings are obvious: The cost is \$0.36 per piece, a saving of \$0.30 per piece. The difference in cost for production of 200 pieces would be \$60.00.

This can only be realized because of the short time required to index the inexpensive, throw-

A 64½-in. Tungsten Carbide Boring Bar Is Used in Machining Powder Chambers of the 120-Mm. M58 Gun Tube at the Watervliet Arsenal. Carbides have a high Young's modulus of elasticity and a carbide bar deflects only about one-third as much as a steel one under a given load. In this instance, the use of throw-away insert tooling in the bar and elimination of vibration permitted a change to a harder cutting edge



away insert. Herein, then, lies the secret to important savings: an inexpensive, quickly reproducible cutting edge.

Carbide as a Mechanical Element

Since carbide is not an expensive commodity, much can be said for its use as mechanical elements in the field of metal cutting. Noteworthy among the practical applications here has been its use in the form of boring bars.

Solid pieces of carbide have an important property not found in any other engineering material – a Young's modulus of elasticity of more than 90,000,000 psi. This value is three times greater than steel. It means that solid carbide bars deflect only one-third as much under a given load. Bores with a length-to-diameter ratio of 10 to 1, and more, can be accurately produced with these carbide bars. The elimination of chatter gives better finishes and longer tool life.

The high Young's modulus of carbide has also been applied to grinding quills, and investigations are now being conducted with solid carbide, single-point tools. These, it is believed, can be used where conditions require a small shank cross-section, superior finish and extreme accuracy.

The intelligent use of "throw-away" inserts, especially when complemented with solid carbide mechanical tooling elements, can lead to a new concept in low-cost production.

A Pattern for Production

Better Hot Work Toolsteels and Improved Forging Dies Benefit Fabricators

By STEWART G. FLETCHER*

EVEN THOUGH MODERN TOOL AND DIE STEELS possess the same basic composition they have had for years, today's materials are far superior in performance because of quality improvements. They have also been helped by minor changes in analysis to better balance their properties. Constant education in the proper use and heat treatment of tool and die materials has added greatly to their utility.

*Vice-President, Technical Director, Latrobe Steel Co., Latrobe, Pa.

Hot work die steels are an exception, for their alloy content is now being juggled about very considerably. With extrusion, die casting, and plastic molding growing rapidly, the requirements for hot work die steels have tended to outstrip their capabilities. Many laboratories are working on these problems, and while it is doubtful that a really major contribution will be brought about by changes in composition alone (at least without going to alloys based on the refractory metals), significant progress is being made.

Some of the principles learned in high speed alloying – for example, use of properly balanced vanadium and carbon additions to improve wear resistance of hot forging dies without sacrificing resistance to cracking – are actively being pursued. Dies for forging jet engine buckets from superalloys have been greatly improved in recent months as a result of this development and even greater improvements are expected in the near future.

Even in this category, however, any change in alloy has been overshadowed by work to improve the quality of product. Since dies most often fail by thermal fatigue and cracking, cleaner, sounder steel has reduced this tendency markedly.

Research Aimed at Major Problems

Given below are some of the areas of tool and die steel technology in which research effort is being directed.

1. **Better dimensional control in heat treatment** – Ideally, a tool or die should be finish machined, then heat treated, sharpened and put in service. Present steels change size and warp in heat treatment too much to allow this; consequently expensive finishing operations are necessary. This effect is becoming even more significant because industry is requiring more and more precision in its products. Close chemistry control, and refined heat treating practices help, but anisotropy still persists and requires close study.

2. **Better machinability and grindability** – Toolsteels are traditionally hard to machine and grind. Significant advances were made several years ago when sulphurized toolsteels were introduced by Latrobe Steel Co., but additional improvements are needed.

3. **Adaptation of vacuum melting techniques** – When tools and dies are used to their opti-

mum capability (unfortunately, this is very rarely the case), the additional cleanliness and improved mechanical properties of vacuum melted toolsteels will become significant.

A Pattern for Production

New Carbide for High Speed Cutting; Ingot Structure Emphasized in Toolsteels

*By W. E. MONTGOMERY and E. W. KALB**

PROBABLY THE MOST SIGNIFICANT characteristic of modern cutting, so far as its influence on cutting tool metallurgy is concerned, is high speed of operation. In evaluating the properties for a cutting tool operating at high speed, the following points should be considered:

1. The cutting tool material must be harder than the material being cut. Cutting efficiency depends largely on the difference between the hardness of the cutting tool and the material it is cutting. The greater the difference, the greater the operating efficiency.

2. A cutting tool must retain a large measure of its hardness at elevated temperatures. It is characteristic of a metal cutting operation that as the speed increases the temperature generated at the tool-chip interface increases. A good cutting material is one which not only has high hardness at room temperature, but also possesses the capacity to retain its hardness in the cut.

3. The cutter must have sufficient mechanical strength to resist the tendency of the cutting forces acting on the tool to cause fracture.

4. The coefficient of friction must be low to facilitate chip flow and to minimize the tendency of chips to weld to the cutting edge.

New Carbide Cutting Material

Because of its ability to retain hardness under the most extreme cutting conditions, Firth Sterling's metallurgists feel that, at least for the immediate future, some form of conventional carbide offers the best basis for a finishing material capable of operating in the high speed ranges now coming on the scene. This satisfies the first two of the necessary properties noted above. We believe that the third property, strength, can be satisfied only by binding the carbide particles together with a metallic binder sintered in liquid phase. Accordingly, our research work has developed a new material for high speed machining, called grade WF. It is basically a titanium carbide, with nickel as a binder, and containing molybdenum carbide as an alloy addition.

Titanium carbide is considerably harder than tungsten carbide and it retains most of its strength at temperatures as high as 2500° F. This hardness-retaining characteristic, plus the peculiar ability of the binding matrix to resist erosion of the chip at high speeds, appears to make this material ideal for the purpose for which it was designed.

What this means in a practical sense is illustrated by the example below. On a typical cut on mild steel with all conditions except speed maintained constant, a number of cutting materials were tested to determine their maximum effective cutting speeds with these results:

Carbon steel	65 sfpm.
High speed steel	125
Cast cobalt alloys	225
Carbide	
semi-finishing steel grades	400
precision finishing steel grades	550
Grade WF	1500

On other cuts, in production, the new carbide has been used at speeds as high as 2000 sfpm.

Good Strength Properties

Optimum cutting speeds for this grade approach those for the best ceramic tool materials, but its superior strength allows it to take severe cuts usually resulting in greater weight of metal removed per unit of time. The graph in Fig. 1 showing tool life as affected by cutting speed, based on actual service testing, illustrates the excellent wear properties of this new grade.

One plant employed the new carbide for boring an S.A.E. 1045 steel casting. Here, the surface speed ran as high as 1700 sfpm. Hardness of this casting was Rockwell C-38, and it was necessary to hold the bore to a 0.0002-in. limit on a 7-in. diameter bore, which was 6½ in. long. Using a depth of cut of 1/16 in., and a feed of 0.002 in., the user completed six pieces

*Mr. Montgomery is Chief Engineer, Carbide Div., and Mr. Kalb is General Manager, Steel Sales Div., Firth Sterling, Inc., Pittsburgh.

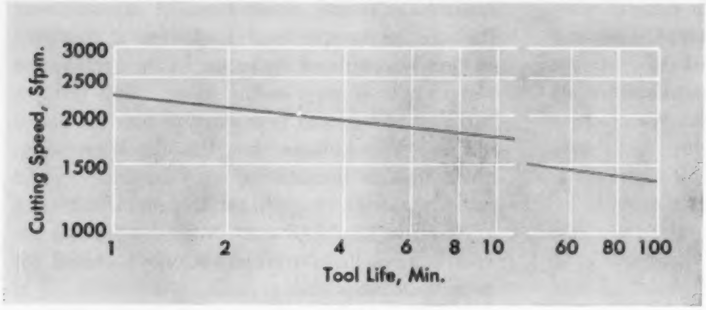


Fig. 1 – Tool Life of New Carbide at Various Cutting Speeds. Test log on A.I.S.I. 4140 steel, Brinell hardness 175. Tool life in minutes to 0.030-in. wear land. Depth of cut, 0.125 in.; feed, 0.005 in.

within the allowable tolerance limit before indexing became necessary. Using conventional carbides, it had not been possible to complete even one piece.

In selecting applications for high speed cutting materials, the engineer must consider carefully their inherent physical characteristics. Such materials are extremely hard and this, in large part, accounts for their useful properties.

Unfortunately, as hardness of the carbide increases, the transverse rupture strength decreases. Selection of a type for a particular application then becomes a compromise to suit the conditions of the cut. Because of their lower transverse rupture strength, greater consideration must be given to the conditions under which our new carbide, or any of the harder carbides or ceramics, are presented to the work. The following points are important:

Cutting tips should be mechanically held, if possible, in order to utilize all the strength built into the material for useful work. Because of the different coefficients of thermal expansion between a steel shank and the carbides, brazing induces an inherent stress in the carbide tip which weakens it. Mechanically held inserts, on the other hand, are not stressed and are at full strength when put to work.

Negative Rakes Recommended

In nearly all instances, satisfactory results will be realized only through the use of negative rakes. The inclination of the insert toward the work, because of the negative rake, distributes cutting forces in such a way that they are opposed by equal forces from the supporting tool holder. The result: The insert is loaded in compression, and the carbides are characterized by extremely high compressive strength.

On the other hand, the distribution of forces in positive rake cutting is such that at least part of the insert is loaded in shear, a condition which is conducive to premature breakage of the harder cutting materials. However, in spite of the limitations which must be put on the use of high speed carbide and ceramic cutting materials, there are many applications at this time particularly suited to their use.

Improved Die and Tool Steels

In tool and die steels, metallurgical improvements are coming from several directions. Increasing emphasis is being placed on controls in steelmaking such as closer control of slag, de-oxidizing procedures, and temperature and mold design in order to improve cleanliness and attain minimum segregation. Closer control of rolling and forging practices, as well as heating cycles, is maintained in order to insure optimum response to heat treatment. Benefication by a consumable melting process, such as the Hopkins process, is being investigated by Firth Sterling as a means to improve ingot structure, reduce segregation, improve physical properties and response to heat treating.

While temperature and variations in mold design are important for minimizing segregation in alloy tool steels, other innovations will further improve quality. Seeding and sonic vibrations are laboratory approaches to improving ingot structure and soundness. In addition, work is being done on improving ingot structure by various methods of vacuum teeming to control gases with their accompanying difficulties, such as flaking and slits, which show up in the finished tools.

Studies of Basic Compositions

Further improvement in toolsteels will result from study of chemistry of the materials including such factors as the effect of residual elements on physical properties. Not only will the negative effects of residuals be studied,

but also the possibilities of improving mechanical properties by the addition of specific elements. In the future, we will benefit a great deal from the work we are doing on mechanical properties required by materials for jet engine and missile applications. In all probability, a new family of steels will evolve, based on the precipitation hardening family of high-temperature alloys, such as A-286 and M-252.

A Pattern for Production

Working of Metastable Austenite Promises to Improve Toolsteels

*By R. F. HARVEY**

IN THE COLD WORK DIE FIELD, a new air hardening grade designated "Airque V" is finding wide acceptance. The analysis of this new steel is 1.25% C, 0.50 Mn, 0.30 Si, 5.25 Cr, 1.15 Mo, 1.00 V. It combines the wear resisting properties characteristic of the high-carbon, high-chromium grades with the high degree of toughness and nondeforming properties for which the standard 5% chromium, air hardening grades are well known.

A new development in general-purpose hot work steels is the use of the 3½% chromium-vanadium grades with combinations of molybdenum or tungsten. These compositions, which have higher red hardness and resistance to tempering than the standard 5% chromium hot work steels, have been particularly successful for extrusions. Vastly improved die materials or methods of reducing friction are needed for the extrusion of steel, high-temperature alloys and refractory metals. Even with molten glass as a lubricant, die life in extruding stainless steel is limited to about 10 or 12 billets. A breakthrough here could profoundly change steel producing and fabricating processes.

High-Speed Machining

The future will see machining operations carried out at speeds well beyond that possible with today's machines. Tests made by firing a workpiece out of a rifle past a cutting tool indicate that surface speeds as high as 160,000 ft. per min. are feasible. At these fast rates, high speed steels are superior to carbides. Under development is a new composition which is hardenable to about Rockwell C-70.

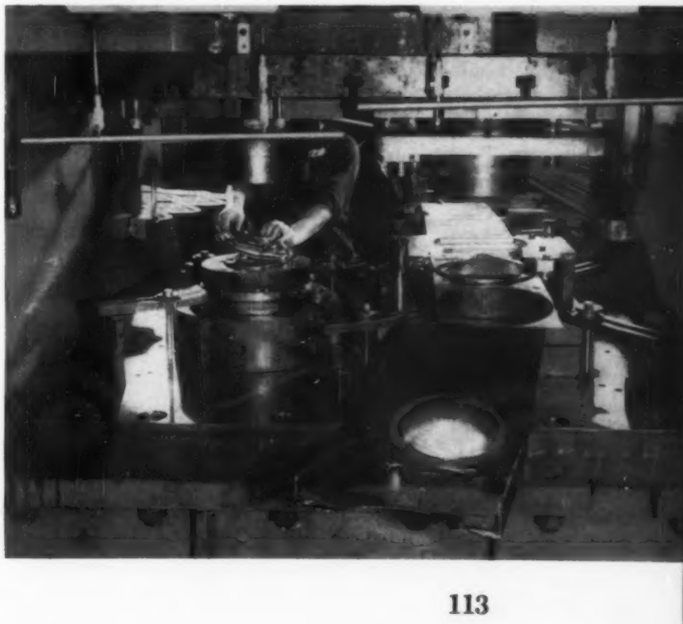
Because of the improved mechanical properties obtained by working alloy steels in the metastable austenitic condition, increased use of this technique on toolsteels (U.S. Patent No. 2,717,846) is anticipated. On high speed steels, mechanical working in the metastable austenitic condition changes the microstructure and gives higher hardness (2 to 3 points) after hardening and after tempering.

Precipitation Hardening Toolsteels

While some precipitation hardening steels are used for high-temperature and corrosion resisting applications, this method of hardening steels has never been applied extensively to tools. Under development are new compositions of this type for applications such as plastic molds and dies for die casting zinc and aluminum. For brass die castings, present steels have definite limitations and need improvement.

In recent years improvements have been made in steel processing to minimize distortion

Automotive Brake Mounting Backing Plates Are Stamped From Hot Rolled Sheets on This 400-Ton Press at the American Stamping Co., Cleveland. Two stamping operations are combined: At right, the blanking and first forming operation is done on one set of dies. Plates are then placed by the operator onto the second die, at left, where the second forming is performed



*Research Metallurgist, Braeburn Alloy Steel Co., Braeburn, Pa.

and out-of-roundness on unground hobs and form relieved cutters. It is anticipated that these procedures will also prove beneficial to manufacturers of thread roll dies and other components since costly finish grinding may be minimized or eliminated.

A Pattern for Production

New Toolsteels for Improved Abrasion Resistance and Cutting of Superalloys

*By THOMAS W. GABRIEL**

DIFFICULTIES IN CUTTING high-temperature alloys and some nonferrous metals, such as Zircaloy, have spurred the development of several modified grades of high speed steels. Work has also gone forward to devise high speed steels with a longer cutting life and it appears that M-7, with a slightly higher vanadium analysis than M-1, is receiving wide acceptance particularly for cutting the so-called normal grades of steel.

Jessop is deeply involved in the improvement of toolsteels for higher abrasion resistance. One application will be in molds, primarly for ceramic materials. We are also working on developments whereby these abrasion resistant materials may be clad with a soft steel backing for sliding abrasion, with the added advantages of shock resistance and ease of attachment. Satisfactory progress is being made here when the clad material is used as a flat rolled product. However, where form, and control of form after heat treatment, are factors, new techniques are needed to overcome difficulties which still exist.

Progress in Dies for Drawing and Blanking

While cast-to-shape toolsteels have been used as dies in the cold forming of automobile bumpers for some time, progress is being made with these steels in drawing sheet steel and to some extent in blanking thin-gage material. Some experimental work is also being done with these tools in extrusion, particularly of aluminum, for backers and dummy blocks but not for the die itself.

*Vice-President – Commercial, Jessop Steel Co., Washington, Pa.

Precision ground toolsteel, commonly referred to as flat stock, offers die shops an advantage in that the pieces can be marked without preliminary machining. Also, there is a growing interest in the low-temperature air hardening grades – A-4 and A-6 – for general tool and die work because of their relative freedom from movement in heat treating at 1500 to 1600° F., with air quenching. For jigs and fixtures some toolmakers are using air hardening fixtures, in the same grade of toolsteel as the die. These are used to hold complex dies securely to minimize growth or movement during heat treating.

A Pattern for Production

Plastic Tooling Proves Useful When Applied Within Its Limitations

STAFF REPORT

THERE IS A LESSON to be learned from the automotive industry when it comes to plastics for tooling. Estimates place the total outlay for plastic tooling among the auto companies at close to $30 million annually. Earliest interest was focused on plastics for stamping dies. Today, however, plastics do not find great use in this application compared to conventional die materials.

Why this is so probably stems from the initial "oversell" of plastics, their indiscriminate use based on recommendations of those not familiar with the problems encountered in forming metals. It has therefore been necessary for auto engineers to back off somewhat from their early enthusiasm.

By far the most extensive application of plastics lies not in dies but in the intermediate tooling. These include duplicate models, spotting and inspection fixtures, templets and prototype panels. In the auto industry, tooling starts from the clay model of a new design. From this, drawings are made of the various panels, then master models of mahogany which are replicas of sections of the original clay model. Plastics enter the picture now in the form of duplicates of these master models – one

for constructing dies, one for constructing assembly fixtures, and a third for constructing inspection fixtures.

Construction of these duplicate models is a critical operation. Basically, it consists of duplicating the desired surface as a skin of resin laminated with glass cloth. This lamination of resin and glass cloth, generally less than ½ in. thick, is then mounted on a rack for structural rigidity and dimensional stability. Dimensional stability of the duplicates is an absolute necessity. Obviously the duplicates must not change shape with age, else when fixtures are placed into production, perhaps months later, the panels from the dies may not check out.

Resin-rich lamination (resin in excess of 50% by weight to glass cloth) and poor technique in constructing the supporting racks are the principal causes of distortion in the model. If the supporting rack is of metal construction, it must be normalized to eliminate residual stresses; if constructed of plastic tubing, it must be precured. This must be done before the rack is joined with the laminated duplicate which it is to support.

Checking Fixtures Made From Reinforced Plastics or Combinations of Steel and Plastics Are Used Extensively at Chrysler Corp. Shown here, the outline, contour and hole locations of tailgate panel for a Plymouth Suburban is being checked on a plastic fixture

Plastic Dies

As pointed out earlier, plastics have not proved to be a universal die material. But plastic dies, most of them epoxy resin, are being successfully used today by those who are fully aware of their limitations. Generally, plastic dies offer potential economies in short production runs, for experimental and prototype cooling, and where quick production with short lead time is desired. This last advantage may be lost, of course, because of delays in constructing follow-up dies such as those used in trimming which are usually made of conventional die materials. Plastic prototype dies are also used when the feasibility of a production die is questioned after design of the part or design of the steel die.

Aircraft companies use plastic dies extensively. In stretch forming of panels, for example, plastic dies have proved suitable for low-volume production runs which are common in the aircraft industry. Dies are usually laminated or cast plastics. With plastics, particularly in large castings, the engineer must contend with shrinkage resulting primarily from the exothermic reaction between the epoxy and the hardening agent. Heat released as the plastic sets raises the temperature to over 200° F. Contraction is on the order of 0.00004 in. per in. per ° F. as the plastic cools. To offset this, plastics men add organic or inorganic fillers such as steel and glass fibers – even gravel. These not only reduce contraction but change other properties such as strength and thermal conductivity.

Dies may also be made in the form of a plastic facing about ½ in. thick on a cast metal core, such as Kirksite or iron.

New Technique

One of the most promising die developments is that of molecular deposition. In this process, a nickel compound in the gaseous state is brought in contact with a heated male or female model in a closed chamber. Thermal decomposition of the gaseous compound occurs at the surface of the model and a shell of nickel up to ½ in. in thickness is deposited. For dies the shell is made about ¼ in. thick. Although the nickel shell may be self-supporting, it is often backed up with a plastic core.

What are the limitations of plastic dies? For one thing, they will not set a sharp radius. Nor will they tolerate burrs on the sheet metal blanks without being scored. Almost perfect metal flow over a plastic die is necessary; wrinkling will soon cause localized wear.

MP

Special Report
Modern Tool Materials and Metal Fabrication

Molybdenum . . .
a Material for Steel Extrusion Dies

*By W. L. STEINBRENNER**

Molybdenum makes a good die material for hot extrusion because of its high-temperature strength at extrusion temperatures. It is comparatively easy to machine and is resistant to galling during extrusion of steel. Dies fabricated from molydenum outlast conventional steel extrusion dies by many times. (W24n, F24; Mo, 17-57)

THE EXTRUSION DIE IS undoubtedly the most critical factor restricting greater use of the hot extrusion process for steel and titanium fabrication. Dimensions, tolerances and section configuration of hot extrusions are limited by the physical characteristics of currently available die materials which are capable of withstanding to only a rather limited extent the service conditions imposed during hot extrusion. The seriousness of this problem is partially indicated by three contracts presently being sponsored by the Air Force for the development of extruded steel and titanium airframe components. One of the major phases of this investigation is concerned with the extrusion die.

In choosing a material for hot extrusion dies two basic factors must be considered – physical properties and cost. Both of these must be examined in detail to evaluate the full potential of a particular die composition.

Analysis of the service conditions to which a hot extrusion die is exposed suggests that a good die material should be resistant to thermal shock, shock loading, galling and flow (or "wash").

Spalling of the die surface exposed directly to the extruding metal cannot be tolerated because such a condition generally leads to premature die failure. An extrusion die also must be capable of withstanding shock loading which results from rapid change in stress distribution during the extrusion cycle. Further, the die should not gall. This would not be a problem if complete lubrication could be maintained throughout the entire extrusion.

A metallographic study of hot work die steel indicates that the surface layer of the die directly exposed to a hot steel billet being extruded at 2300° F. reaches temperatures in excess of 2000° F. to a few thousandths of an inch in depth. A die material, therefore, should possess sufficient strength at temperatures near that being used for extrusion so that the surface of the die does not flow or "wash". This property, flow strength – commonly thought to be wear or abrasion resistance – seems to be characteristic of the tensile strength of the die material at elevated temperatures.

Cost Considerations

The two most important methods of fabrication for steel and titanium extrusion are shell mold casting and machining from forged

*Research Engineer, Stainless Steel Section, Graham Research Laboratory, Jones & Laughlin Steel Corp., Pittsburgh. In acknowledgement, Universal-Cyclops Steel Corp. made the initial suggestion of using molybdenum for hot extrusion dies, and supplied the first three die blanks investigated. The author also wishes to thank H. M. McCullough of that company along with J. K. Seyler, R. F. Kegel and T. E. Dancy of Jones & Laughlin Steel Corp. for their cooperation and assistance during this investigation.

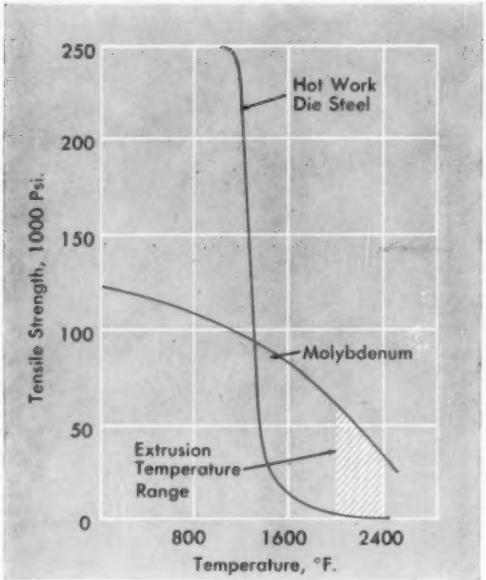


Fig. 1 – Comparison of the Tensile Strength of Molybdenum and a Hot Work Die Steel With Respect to Temperature

blanks. Because of high machining costs, the trend has been to cast dies since these require very little finish machining. A good die material, therefore, should either possess satisfactory casting properties or (if not castable) good machinability.

The cost of die stock is probably given primary consideration by most users of extrusion dies. Material cost, however, must be judged in relation to the other factors which have been discussed, or else promising materials, although relatively high in cost, may be disregarded without realizing their full potential. An expensive extrusion die must yield significantly higher life in order to be competitive with lower-priced dies.

Molybdenum Has Good Die Properties

Molybdenum, a high-priced metal, possesses a number of physical characteristics which make it a potentially good hot work material. It melts at 4760° F., has a high recrystallization temperature, and good mechanical properties at elevated temperatures. Its high thermal conductivity rapidly dissipates heat from the die surface. The possible presence of a lubricating film of one of its oxides minimizes the amount of die galling which occurs during extrusion and the subsequent amount of die dressing required.

It has been previously mentioned that during steel extrusion the surface of hot work steel dies can reach temperatures in excess of 2000° F. Figure 1 shows the comparative difference between the tensile strength of molybdenum and a hot work die steel with respect to temperature. As can be seen, molybdenum has a significantly higher tensile strength than the hot work die steel at temperatures above 1300° F., and consequently the flow strength of molybdenum is higher than that of the hot work die steel in this temperature range. Thus, with molybdenum there is less tendency to flow or "wash". Below 1300° F., however, the flow strength of the hot work die steel exceeds that of molybdenum. The bulk of the steel die is,

Table I – Production Data on Molybdenum Alloy Hot Extrusion Dies

Die	Profile	Die Face Diam.	Extruded Area	Billet Diam.	Extrusion Ratio	Material Extruded	Extruded Length	No. of Extrusions
1*†	A	2 in.	0.271 sq.in.	4 in.	48	C 1018	22.2 ft.	146
2*†	B	3	0.679	5	34	C 1018	22.0	64
3	C	3	1.082	5	21	4150	12.0	95
4†	D	2	0.292	4	44	C 1010	17.5	15
5‡	E	2	0.285	4	45	C 1020	19.0	304
6	E	3	0.285	4	45	C 1020	19.0	425
7†	F	3	1.200	5	19	410	10.0	91
8	G	3	1.399	5	16	8620	13.3	210
9	H	3	1.250	4	10	8620	11.0	308

*Die preheat, 250° F.; all other dies preheated at 700° F.
†These dies broke during trial runs; all others were still usable when extrusion runs were complete.
‡Fabricated from disks cut from hot rolled bar; others fabricated from forged blanks.

therefore, more stable than that of molybdenum. Profile backers must be used with the molybdenum die because of the low bulk flow strength. Even then slight deformation of the die will occur. This can be used to advantage because the deformation is not great enough to cause failure of the die; often it is just sufficient to compensate for the wear on the bearing surface. In some instances, certain die dimensions must be opened a few thousandths of an inch after 100 or more extrusions. One should not be led to believe that the superior performance reported for molybdenum dies is due principally to slight deformation or closing of the die. It will be shown that superior die life has been achieved with little or no die closure. The amount of die closure is dependent upon the profile of the die and the specific extrusion pressure.

Molybdenum has a thermal conductivity almost twice as great as hot work steels. There is a good possibility that the surface of a molybdenum die never reaches the temperature experienced by a steel die. The lower the surface temperature of the die during extrusion, the higher is its flow strength. Consequently, the amount of flow of the die surface will decrease.

Although shock resistance of molybdenum is inferior to that of hot work die steels, it is more than adequate, after the die is properly preheated, for hot extrusion.

In our investigation molybdenum dies exhibited little tendency for galling during steel extrusion. Generally, the molybdenum dies were cleaned in the die holder and run continuously, whereas conventional hot work steel dies were removed from the die holder after each extrusion and cleaned and dressed. The superior nongalling characteristic of molybdenum may be attributed to the formation of a very thin film of MoO_3 on the die surface during extrusion. This oxide melts at 1465° F. and reacts with molybdenum to form a lower-melting (1430° F.) oxide, MoO_2, which could act as a lubricant during extrusion. No attempt was made to determine the presence of such a film. It seems very likely that it would form under extrusion conditions.

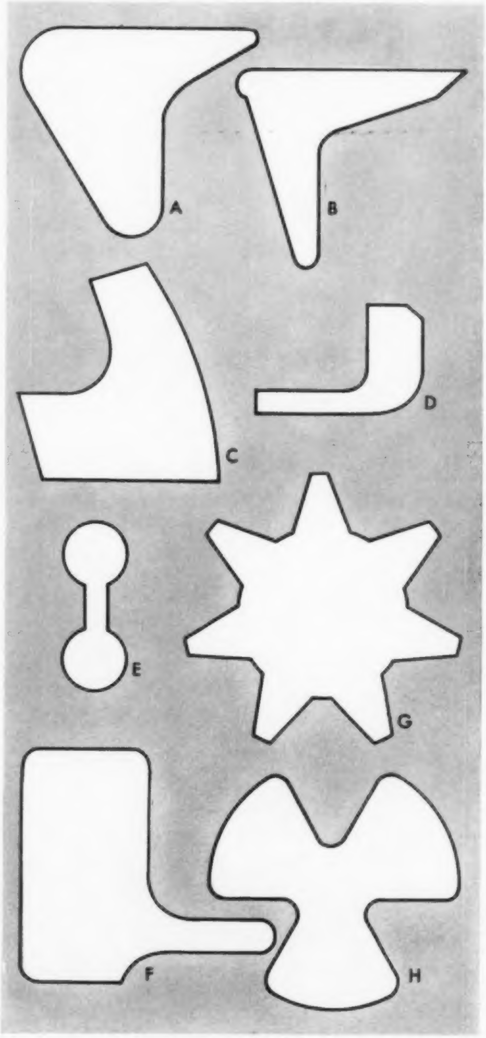
No molybdenum dies were evaluated for extrusion of titanium. Some limited work has been reported but additional work is needed.

Easier Die Fabrication

A number of molybdenum dies were fabricated from either forged blanks or disks cut from hot cold rolled bar. The composition of both the forgings and bar stock was 99.5% Mo + 0.5% Ti; the hardness of each was Rockwell B-95 to 100. This low hardness, compared with conventional die materials, greatly facilitated die machining and bench work. Dies were initially machined on standard diemaking equipment and subsequently finished by hand. Finished dies were given no heat treatment, but were used in the as-received condition.

Because a molybdenum die is relatively soft even after use, it is easily reworked to a new profile of larger dimensions. This is not feasible with used steel dies due to their higher

Fig. 2 – Molybdenum Die Profiles (Actual Size)



hardness. Softening them for reworking is not practical.

Thus, we see that when molybdenum is used, three savings can be achieved during die fabrication. Molybdenum dies are easily machined, require no heat treatment, and can be reworked into new profiles after use.

Molybdenum Die Performance

A series of investigations were undertaken at the J&L extrusion plant to evaluate the performance of molybdenum dies during hot extrusion of steel. Before discussing the performance of the molybdenum dies, a brief description of the extrusion plant follows.

J&L has a 1000-ton horizontal press, manufactured by Loewy-Hydropress, which is equipped with containers for accommodating 4 and 5-in. diameter billets. The extrusion dies used with these containers have face diameters of 2, 3 and 4 in. and are about 1 in. thick. The press has been used almost exclusively for ferrous extrusion. A 60-cycle induction furnace is used for billet heating. Glass is used as a lubricant* and most extrusion is done at 2300° F. Almost all extruded bars are subsequently cold drawn.

A total of nine molybdenum dies were fabricated into the various profiles shown in Fig. 2

*Use of glass as a lubricant is protected by the Ugine-Sejournet patents.

Three types of steel billet stock – carbon, low-alloy and stainless – were extruded at 2300° F. The extrusion ratio of the various sections ranged from 10:1 to 48:1 and extruded lengths up to 22.2 ft. were produced.

Operating data and production performance for each of the molybdenum dies is given in Table I. As indicated, four of the dies broke in service. In each instance, however, some external factor was responsible for their failure. Initially the first two dies were only preheated to 250° F. which was found to be insufficient. Cracks, developed in regions of high stress concentration, led to complete failure of the die. Preheat temperature was raised to 700° F. and cracking was not observed in the dies. In another instance of die failure, a profile backer was not used and the die fractured. The fourth instance of die failure occurred when a die was being hammered in an attempt to remove it from the die holder. The other five dies produced from 95 to 425 extrusions and were still in a serviceable condition after the respective extrusion orders were completed.

The tendency for the die profile to close slightly during service has been discussed previously. This condition precluded the evaluation of these dies on the basis of die wear. All of the extrusions produced with these dies with the exception of profile F (see Fig. 2 and Table I) were subsequently cold drawn. The amount of variation in extrusion dimensions which can be tolerated for cold drawing depends upon the bar material, section profile and the specific cold drawn dimension and its tolerance. There-

Fig 3 – Die 8 and 9 (See Table I) After 210 and 308 Extrusions, Respectively. An insignificant amount of wear occurred on the protruding tips of each profile

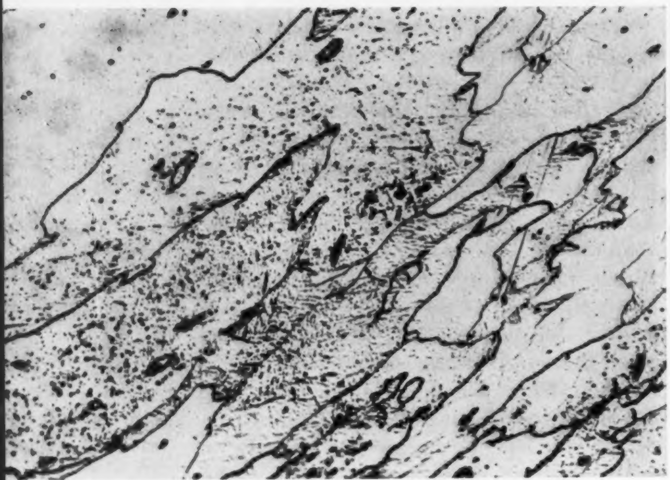


Fig. 4 — Hot-Cold Worked Microstructure of a Molybdenum Die. Etched electrolytically in a solution of methyl alcohol, sulphuric acid and hydrochloric acid; 100 ×

fore, the amount of variation in the extrusion dimensions may be only 0.005 in. for one and as much as 0.050 in. for another. However, under any circumstance, closer tolerances were maintained for a given profile with molybdenum than with any conventional die material. Figure 3 shows dies 8 and 9 (Table I) after they had produced 210 and 308 extrusions, respectively. An insignificant amount of die wear was observed on the protruding tips of each profile. Because the extrusion ratio of these two sections was relatively low (16:1 and 10:1), there was little die deformation or closure.

Are Hardness and Microstructure Important?

The hardness and microstructure of dies 5 (forged blank) and 7 (rolled blank) were studied to ascertain further the physical characteristics of molybdenum which give it superior die life during hot extrusion. The dies were sectioned along two radii and a hardness traverse was taken on one of the sectioned surfaces at various depths from the bearing radius. The Knoop hardness values, taken with a Tukon Hardness Tester, were converted to Rockwell B. It was found that the hardness of the extrusion surface of both dies was about Rockwell B-101 to 103. The hardness of the dies decreased to about Rockwell B-95 to 99 at 0.050 in. from the extrusion surface. This small increase in surface hardness results from slight hot-cold working of the die surface during extrusion.

An examination of the microstructure of dies 5 and 7 revealed them to be typical of hot-cold worked material. The die stock was originally forged or rolled somewhat below the recrystallization temperature which is about 2300° F. for slightly worked material, decreasing to 1700° F. as the material becomes heavily worked. The conditions imposed during steel extrusion have not changed the original hot-cold worked structure. Figure 4, a photomicrograph of die 5, shows typical hot-cold worked microstructure.

The hardness and metallographic study did not indicate that the resistance to wear of the molybdenum dies can be attributed to a significant work hardening of the die surface or change in the microstructure. The principal characteristic which seems to be contributing to superior die life is the high flow strength of the material at the extrusion temperature.

Future Development Suggested

It is well known that the addition of alloying elements to a metal increases its recrystallization temperature and generally improves its high-temperature mechanical properties. The basic criteria for a good metallic die material seems to be that it must possess a high recrystallization temperature. Further alloy additions may improve the hot extrusion die qualities of the 99.5% Mo + 0.5% Ti composition. Unfortunately, alloying elements will increase the hot working difficulties of molybdenum with respect to the capacity of present equipment for forging and rolling molybdenum bar stock. Consideration also should be given to improving the strength of molybdenum alloys at intermediate temperatures so that somewhat better bulk stability of the die can be obtained.

Several other metals which possess a high recrystallization temperature are worthy of mention. These include columbium, tantalum and tungsten. Although tantalum and tungsten have higher recrystallization temperatures than molybdenum, they have distinct disadvantages. The cost of tantalum and fabrication difficulties of tungsten prohibit their consideration for hot extrusion die application at the present time. Recrystallization characteristics of columbium are similar to molybdenum. Thus, columbium offers essentially the same potential for hot extrusion die application. Columbium may eventually become less expensive than molybdenum, and columbium alloys should be capable of achieving high-temperature properties comparable to molybdenum.

MP

Special Report
Modern Tool Materials and Metal Fabrication

Precision Cold Extrusion of Metals

*By R. A. QUADT**

The process, which offers rapid production of parts with close dimensional control, has been used successfully to fabricate steel, aluminum, titanium and some of the uncommon metals. (G5; Al, Zr, ST, Ti, Cb, Ta, V, Be)

WHERE DOES PRECISION EXTRUSION fit into the metal fabrication picture today? Briefly, here are some of the notable advantages:

- It often is the most economical method of fabrication. Billet recovery is high; scrap recycling costs are reduced. Expensive machining operations are avoided.
- It is carried out below temperatures at which metal-gas reactions occur. Thus, contamination of the metal is eliminated or decreased.
- Cold worked structures are produced; no recrystallization occurs.
- Precise dimensional control is possible.

True, precision cold extrusion has limitations, and it does not have universal application. But it holds a definite place of importance in the field of metalworking.

What It Is

When we speak of cold extrusion we do not, of course, refer to the relative temperature of the operation. Rather, we are specifying that the temperature at which the deformation of the metal billet takes place is substantially lower than the recrystallization temperature. With aluminum alloys, the extrusion temperature is usually ambient or only sufficiently above room temperature to insure proper lubrication control. For all the other metals to be discussed, billet extrusion temperature ranges between 450 and 1000° F. depending upon the metal or alloy, the requirements of the lubricant, and the final configuration or tolerances desired. The final extrusions, therefore, exhibit the work hardening characteristics of increased hardness and strength, reduced ductility, and a severely distorted crystallographic structure, depending upon the extrusion ratio.

In addition to being below the recrystallization temperature, the extrusion temperature for the several reactive metals investigated is low enough that no protective cladding or coating is required to prevent metal-gas reactions during the entire operation. Surface reactions with hydrogen, carbon, nitrogen and oxygen are avoided or greatly minimized.

Other advantages resulting from the precision cold extrusion process relate to the close dimensional tolerances possible and the higher metal recoveries inherent as compared to hot extrusion. In cold extruded tubular shapes dimensional tolerances in the range of ± 0.001 in. are quite feasible while inner diameter and outer diameter tolerances of ± 0.005 to ± 0.010 in. are typical. Concentricity is excellent and the minimum wall gage can be specified. This results in weight reductions and lower costs, particularly in tubular shapes of tantalum, columbium, zirconium and other expensive metals.

One of the primary factors influencing the success or failure in precision cold extrusion technology is lubrication. All commercially available lubricants have been tried with varying degrees of success. It has been found necessary to develop an entirely separate lubri-

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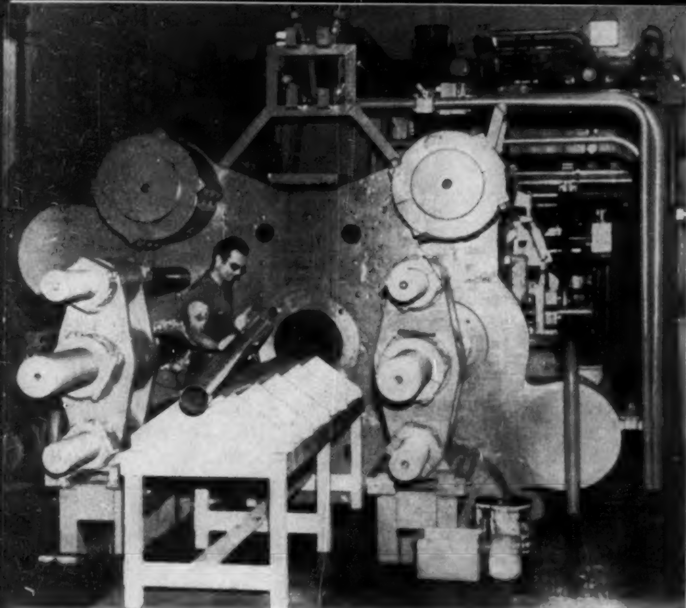

Fig. 1 — 3500-Ton Press Specially Designed for Cold Extrusion. Press is constructed with maximum precision and rigidity

Table I — Guaranteed Minimum Properties in Aluminum Cold Extrusions

Aluminum Alloy	Strength		Elongation
	Tensile	Yield	
6011-T6	50,000 psi.	42,000 psi.	7%
2014-T6	65,000	55,000	7
7075-T6	75,000	65,000	7
ZG 73-T6*	80,000	72,000	7
ZG 93-T6*	88,000	80,000	5

*Tentative specifications.

cation technology concurrently with specific cold extrusion programs. Different metals require specific lubricants developed or adapted to their unique chemical or metallurgical characteristics. Final lubricant techniques are further influenced by the requirements of the extrusion design. The entire subject is sufficiently complex to be beyond the scope of this paper and is further complicated by proprietary restrictions plus the recognition that the entire lubrication aspect has not yet been reduced to an exact science.

Work reported here has been performed on horizontal hydraulic presses (Fig. 1) ranging from 200 to 3500 tons, specifically constructed for precision cold extrusion of difficult-to-work metals. The maximum ram deviation from the punch axis is 0.002 in. on power strokes up to 108 in. Ram speeds available are quite nominal; they are controlled for any advance rate up to 180 in. per min.

There is practically no impact, and most cold extrusions are produced by a reasonably slow squeeze not unlike a typical hot extrusion operation. On the largest press, heat treatable aluminum alloys of high strength have been cold extruded in some tubular shapes up to 45 ft. long and in other closed-end tubes up to 20 in. in diameter.

No Trouble With Aluminum

Development work was originally concentrated on cold extrusion of the heat treatable aluminum alloys containing copper, magnesium and silicon. When extruded and heat treated, these alloys had typical yield strengths of 60,000 psi. Some time later the emphasis was placed upon the more complex aluminum alloys containing zinc, magnesium and copper. Typical yield strengths of these alloys ranged from 70,000 to 85,000 psi.

These complex alloys appeared to offer less

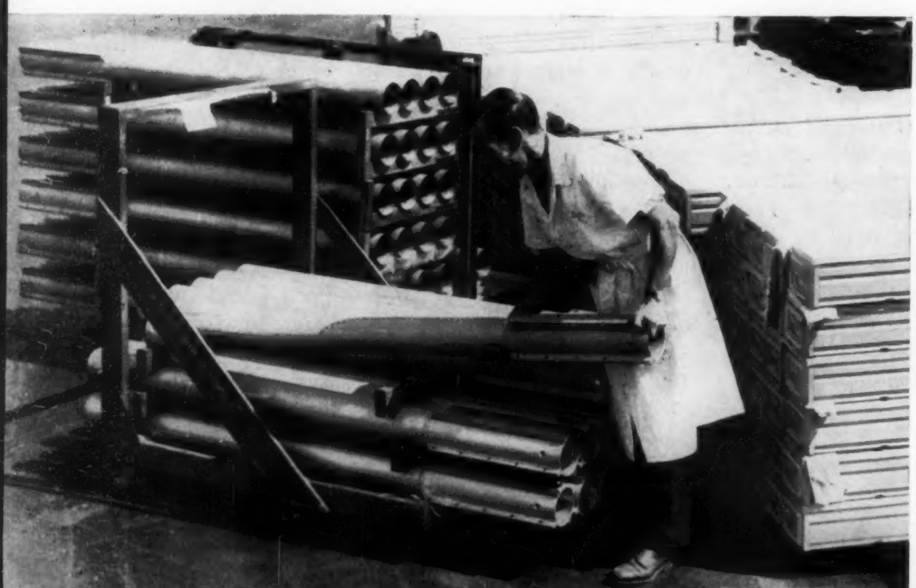

Fig. 2 — Missile Motor Tubes Cold Extruded From a High-Strength Aluminum Alloy. Precision of the process is demonstrated by wall thickness variation which is held within ±0.00075 in. in the as-extruded condition

cold extrusion difficulty than those which were softer and not heat treated. Table I lists some of the high-strength aluminum alloys and the minimum properties guaranteed for engineering design purposes. Figure 2 shows one of the larger and more complicated precision shapes made from these strong alloys.

Table II – Properties of Extruded Unalloyed Titanium

	COLD EXTRUDED (82% REDUCTION)		ANNEALED*	
	99.0% PURE	99.2% PURE	99.0% PURE	99.2% PURE
Tensile strength	130,000 psi.	113,500 psi.	105,600 psi.	91,500 psi.
Yield strength	115,000 psi.	95,000 psi.	79,000 psi.	69,900 psi.
Elongation	13%	12%	17%	18%
Rockwell hardness	A-68	A-64	A-61	A-57

*Annealed 1 hr. at 1450° F. and air quenched after cold extrusion. Specified minimum properties for annealed 99.0% pure titanium are 80,000 psi. tensile, 70,000 psi. yield, 15% elongation. For annealed 99.2% pure titanium, specified minimums are 65,000 psi. tensile, 55,000 psi. yield, 20% elongation.

Of interest is the fine, relatively equiaxed recrystallized grain structure typical of cold extrusions. Since many tubes are predominantly pressure vessels, the circumferential properties are as important as those in the longitudinal direction. It has become possible to guarantee the same properties in the transverse direction as in the longitudinal, even in the sensitive alloys of the aluminum-rich zinc-magnesium-copper series.

The surface finish of these cold extrusions is excellent and generally falls within 30 to 100 micro-in., with 70 being typical. Because precise tolerances are maintained in the as-extruded condition, the only machining operations required are drilling, threading, slotting, trimming to length, and other minor metal removing operations. It is never necessary to remove metal by boring or turning because outside and inside diameters are produced to tolerances within normal machining standards and eccentricity is negligible.

Three grades of zirconium-base alloys have been precision cold extruded in large quantities. These include pure reactor-grade commercial zirconium containing hafnium, and Zircaloy (reactor-grade zirconium with controlled amounts of tin). Most of the precision shapes have been produced for moderator structures in nuclear reactors, nuclear fuel element cladding, and pressure vessels in nuclear reactors. A range of sizes (Fig. 3) has been produced including many unusual shapes, both hollow and solid. An important advantage of cold extruding zirconium is that up to 85% of the billet weight is recovered in the final shape. Costs are lower too because cladding to prevent surface contamination during working is not necessary. Typical extrusion reductions are

Fig. 3 – Zircaloy-2 Tubes Typical of the Shapes Which Can Be Cold Extruded on a Production Basis. Each tube shown has 3½-in. O.D., 0.160-in. thick walls with a heavy flange at the tube base

in the range of 80%. The change in properties of reactor-grade zirconium resulting from the added cold work are as follows:

	Annealed	Reduced 80%
Tensile strength	35,900 psi.	73,000 psi.
Yield strength	15,900	61,000
Elongation	31%	16%
Brinell hardness (500 kg.)	101	150

Large Steel Parts Extruded

Although cold extrusion of steel has been reported during the past few years (see *Metal Progress,* October 1959, p. 122), most of it has been limited to relatively small parts. However, our experience has shown that even large pieces can be cold extruded. One example is in production of tubular booster sections for rocket motors which are cold extruded from 4130 steel. These tubes are about 5 in. in diameter, 44 in. in length, and are extruded with external ribs and have a wall thickness of about 0.160 in.

In Fig. 4 the processing steps in developing a tube blank for subsequent reduction into a thin-walled tube are shown. The material is a special stainless steel for nuclear applications.

Titanium Blanks

Unalloyed titanium of several purity levels has been successfully cold extruded to tube blanks. No unusual problems were encountered and very satisfactory tube stock was produced. The properties of extruded tubes are given in Table II. These extrusions were used as blanks for further reduction to thin-walled tubes of small diameter for condenser and heat exchanger applications. When reduced to final size, tubes are typically ½ in. O.D., 0.025 in. wall thickness, and 20 ft. long. The advantages of using the cold extrusion process were, again, improved recovery of expensive metal, excellent surface and metallurgical structure, and superior concentricity.

Development work on commercial titanium alloys has been unsuccessful because the tool loads during cold extrusion have been excessive and have resulted in tool breakage. Additional work is planned for the hard alloys.

Success With Uncommon Metals

Molybdenum tube blanks from both arc cast and sintered slugs have been cold extruded at about 800° F. Newer alloys of molybdenum have yet to be successfully cold extruded. Here again, tool loads have proved excessive.

Nominal quantities of unalloyed tubes have been produced with cold extrusion reductions up to 75%. In the annealed condition, unalloyed molybdenum tubes have a tensile strength of 75,000 psi., yield strength of 50,000 psi., elongation of 40% and Brinell hardness (3000-kg. load) of 155. Cold extrusion with 75% reduction gives 130,000 psi. tensile, 120,000 psi. yield, 5% elongation and Brinell hardness of 257. At present, tubes with walls of ⅛ in. or thicker, diameters *(Continued on p. 164)*

Fig. 4 – Three Stages in Cold Extrusion of a Ferritic Stainless Steel. Left – solid billet (2⅔ in. diameter by 3¼ in.); center – cupped billet, back extruded at 38% reduction; right – finished tube, forward extruded at 75% reduction. Cupped billet (center) was bored before final cold extrusion of the tube

MP

Special Report

Modern Tool Materials and Metal Fabrication

Precision Forging up to Date

*STAFF REPORT**

Today, many different parts are forged to such close tolerances that little or no subsequent machining is required. For such items aluminum and magnesium are often used, but other metals offer more problems. This article discusses some of the difficulties that forgers have met and solved in research and in regular production to produce close-tolerance parts. (F22, W24n; Al, Mg)

What do you think of when you hear the words "precision forging"? Actually, there is no standard definition. Size, for example, is no criterion. Precision forgings – they may also be called close-tolerance forgings – can be as large as bulky airframe members or as small as a turbine blade. Most forgers seem to feel that the determining factor is: How much machining is required after finish forging? If little or no machining is needed, the part can be considered a precision forging.

This type of forging usually combines close tolerances with small fillets and thin webs with no draft. With such design features incorporated, it is obvious that making a precision forging is much more difficult than describing one. To form virtually every outside dimension so accurately that no further machining is required – and at the same time, to keep the surface uncontaminated while it is at forging heat and being shaped – is quite difficult.

Cost enters the picture, too. For the process to be economical, parts which duplicate each other exactly must be made time after time with little or no adjustment to the equipment. Mass-production techniques are essential.

When all of the difficulties are considered, it is apparent that there is good reason for the comparative lack of progress in the precision forging field. Yet, slow advances continue. This article is intended to outline both the problems and possibilities – and there are many of each – of precision forging.

Two Main Divisions

For convenience, precision forgings will be discussed under two general classifications, the division being determined by the relative ease of forging. The first group includes the light metals, aluminum and magnesium. Being forgeable at moderate temperatures, they are not difficult to maintain at heat while they are being shaped. Protecting the surface – a very important step in precision forging – is also fairly simple for these two metals.

As a consequence, the process is now being used quite widely for the light metals, particularly the high-strength aluminum alloys such as 2014 and 7075. Tons of forged parts (chiefly for aircraft) have been turned out by the forging presses at Wyman-Gordon and Alcoa, two companies which are very active in precision and close-tolerance forging. Though original equipment costs much more (especially for the large and precise forging presses that are sometimes necessary), the saving in sub-

*The editors are grateful for the extensive help received from the following companies during the preparation of this article. Without it, little could have been accomplished:

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Armour Research Foundation, Chicago.

Ladish Co., Cudahy, Wis.

Steel Improvement & Forge Co., Cleveland.

Wyman-Gordon Co., Eastern Div., Worcester, Mass., and Prex Plant, Franklin Park, Ill.

sequent machining is such that the process is definitely economical. Machining large airframe members from the conventional and blocker-type forgings formerly used was an expensive, time-consuming process which required elaborate and massive tracing lathes.

Forging Aluminum and Magnesium

Precision forging – or more accurately, close-tolerance forging – of aluminum and magnesium has progressed much farther than it has for steel and refractory metals for one basic reason. These light metals can be forged at much lower temperatures. Forging at 500 to 900° F. is commonplace, and such temperatures are fairly simple to maintain during processing. Usually, the dies are warmed and held at the approximate forging temperature in some manner (furnaces are commonly used) to facilitate metal flow into every section of the die.

Because of the continuing demand for lighter aircraft which can carry greater payloads, a lot of money has been invested by the government in king-size forging presses to make close-tolerance forgings. Inspired by German developments revealed after World War II, enormous 35,000 and 50,000-ton forging presses were erected at Wyman-Gordon's North Grafton (Mass.) plant and the Alcoa Forge Plant in Cleveland. These huge presses made it possible to forge large airframe sections with greatly improved tolerances. Figure 1 illustrates the potential for savings in material and machining costs.

The main problem, according to forgers, comes in the cost of tooling. Dies for precision forgings are considerably more expensive than the simpler dies formerly used. Also, setup time for a run of precision forgings is longer; this adds to the cost. As a consequence, a fair number of parts must be made if true savings are to be realized from precision forging techniques. The break-even point, since it generally depends on the complexity of the design, will vary quite widely from part to part. For example, if the item has a fairly simple design, a large number of them must be made per set of dies built. Otherwise, the cost per forging (close-tolerance) will be greater than for the same part machined from a blocker-type forging which has wider tolerances. On the other hand, the break-even point is much lower for complicated airframe sections. So much work and time is consumed in machining this type of part from a blocker-type forging that costs rise astronomically even though the forging itself is relatively inexpensive.

Incidentally, if speed is essential, precision forging techniques can be useful for short runs as well as for long runs. The time advantage enters the picture because precision forgings need much less machining. Though more time is needed to machine the dies to precise dimensions, the parts forged in these dies will in turn need little machining. Thus total time-to-delivery will be reduced.

Cost Is Important

A good indication of the cost problem might be gained by considering some of the precautions taken by one producer. First, the bar stock is carefully inspected and prepared because any surface imperfections will appear in the forging. The presses which forge this stock are built with precision features including, among other items, an automatic timer. (The "dwell" time – the time during which pressure is maintained – is quite critical, and cannot be allowed to vary.) Every forging is weighed to within an ounce before the final

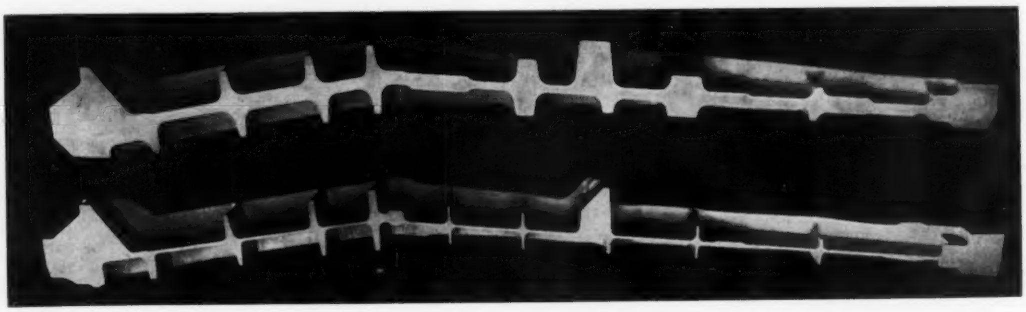


Fig. 1 – These Sections Illustrate the Difference Between Conventional and Close-Tolerance Forgings. For this close-tolerance forging, savings are about 25% in material and 20% in machining cost

Fig. 2 — Cadillac Wheel Disks Being Forged to Close Tolerances on an 8000-Ton Press. Wheels for truck trailers are also being forged

pressing because there is no leeway for overweight (no allowance for flash) or underweight (thin webs do not fill in). All completed forgings are 100% inspected before shipment.

It is apparent that precision forgings are not easy to make. However, that is not the chief worry of forgers today. As far as they are concerned, the major drawback is the lack of demand for airframe sections. Because of the increased interest in missiles, work on newer aircraft has slackened, and this slackening is reflected in the forging field. In general, missiles do not use forged frames such as those used in aircraft.

However, forgers would prefer to find a market much more dependable than either aircraft or missiles. Alcoa is moving in that direction with the forging of wheel disks for automobiles (see Fig. 2) and truck trailers. Trowel handles, connecting rods, and equalizer beams (for trucks) have also been precision forged. It would seem that there is a future for this type of forging in the automotive field. Other areas where such forgings may also be useful are hydraulic equipment (bodies for heavy valves are an example), large electronic equipment such as that in the radar and television industries, and atomic energy equipment. In general, precision forgings of aluminum can be used wherever light weight, strength, and close tolerances are all essential.

The Other Metals

Most of the other metals are another matter entirely because they are forged at higher temperatures. Metals such as titanium, beryllium, molybdenum, tungsten, columbium, tantalum, and the superalloys are difficult to forge as it is. The prospect of forging them to close tolerances as well is definitely not inviting to the average forger. Yet, the process is attracting attention because of the savings that can develop. The refractory metals and superalloys are quite expensive — some cost as much as $70.00 per lb., in fact. Any reduction in material loss (which occurs with subsequent machining of conventional forgings) is at once realized. Also, these metals are difficult to machine; cost reductions can also develop from both the reduction of machining time and the wear and tear on machinery.

So far, however, the numerous drawbacks that occur in forging the refractory metals have inhibited progress to a great degree. The high temperatures needed for forging bring a host of problems which must be solved before the process can become a routine matter. For example, surface protection becomes vital. Without proper protection, steels decarburize, tungsten and molybdenum oxidize rapidly, and titanium picks up appreciable hydrogen at the high temperatures which are needed. Holding precision tolerances under such conditions is very difficult.

Also hard to find are die materials which will withstand the wear that dies incur when used for forging at high temperatures. The property which makes a refractory metal useful at elevated temperatures — resistance to deformation — is the same property which makes the metal difficult to forge. Die materials must stand up to both the stiffness of the metal being forged and the high temperature. The material that can do this — whether it be a superalloy or a suitable die steel — is itself hard to shape to precise dimensions. Lengthy and costly ma-

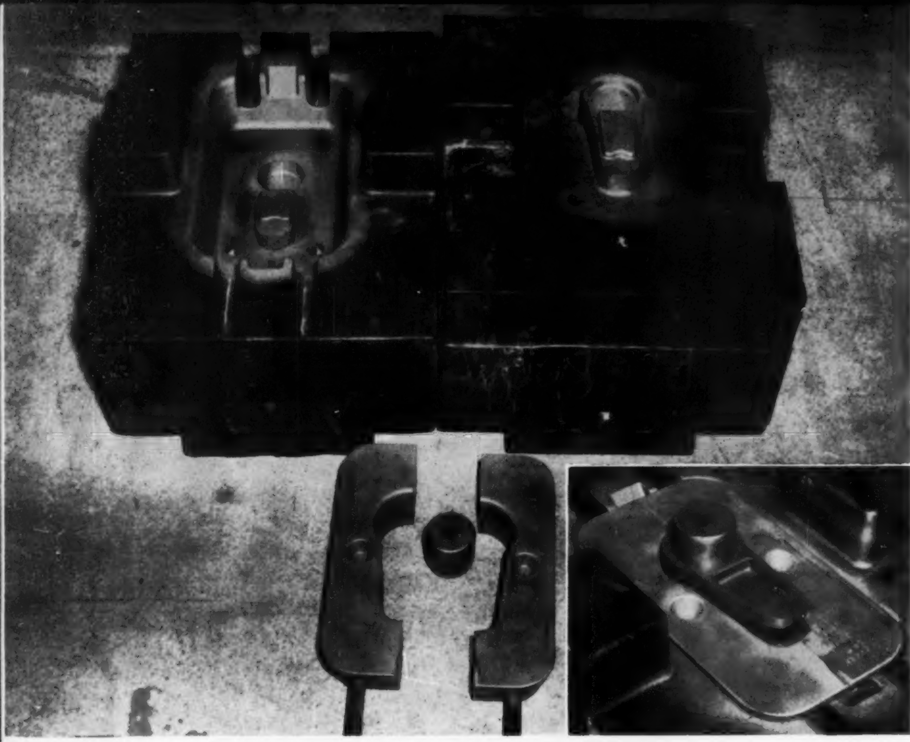


Fig. 3 – Split Inserts Which Are Used in Forming This Experimental Part to Precision Tolerances and Without Draft. Inset shows part which is made of A.I.S.I. 4340

chining may be needed merely to cut the die to the proper shape.

These and other problems have limited the development of precision forging in the refractory metal field. As of now, the only types of parts being precision forged to any extent are turbine blades for jet aircraft. Forging of other types of parts is still in an experimental stage.

However, progress is being made, though at a much slower pace than with aluminum and magnesium. Only a short time ago, the precision forging of the refractory metals was not even considered. Tomorrow, it may be a standard procedure.

Research in Progress

This report would not be complete without some discussion of the research program on close-tolerance steel forging, which was sponsored by the Air Materiel Command. Through Boeing Airplane Co., who handled the prime contract, three forging companies (Ladish Co., Steel Improvement and Forge Co., and Wyman-Gordon Co.) were assigned various projects. Each company was to forge (of A.I.S.I. 4340) a different production item, redesigned as a precision part. The approach to be investigated by Ladish was "multiple dies and multiple parting lines"; by Steel Improvement, "high-speed mechanical presses or impacters"; and by Wyman-Gordon, "dies heated to the approximate temperature of the forging stock". In the time allotted, Sept. 1, 1958 to Feb. 1, 1959, each company was asked to produce a number of production parts for testing by Boeing. This testing was to determine how well these parts met the required specifications in dimensional tolerances, decarburization, and strength. The three subcontractors had varying success.

Multiple Parting Lines And Dies

As mentioned above, Ladish Co. was asked to investigate "multiple dies and multiple parting lines". Drop hammers were to be used for the forging. They started by selecting the design approach shown in Fig. 3, which illustrates the coining die setup. The part was forged with the web in a horizontal position so that the forging could be positioned exactly. After finish forging, hot coining (padding) dies produced the precise dimensions that were needed. (Tools such as those illustrated also make no-draft forgings feasible.) Locks in the blocking and finish forging dies helped to maintain precise alignment. Flash was eliminated before the hot coining operation, and close temperature control was needed at all stages.

As for the die materials, Ladish D 6 A* was

*This patented material is a hot work die steel with relatively low alloy. It contains 0.46% C, 1.0% Cr, 1.0% Mo and 0.50% Ni, and can be heat treated to 250,000 psi. yield strength, 280,000 psi. tensile strength, 10% elongation, 30% reduction in area, and 16 ft-lb. Charpy V-notch. These values are averages from data on eight heats.

used for blockers and finish forging dies, FX (A. Finkl & Sons Co.) for insert holders in hot coining dies, and S.A.E. H-11 toolsteels for inserts in all finish hot coining operations.

Die temperatures were maintained from 350 to 600° F. throughout the forging, except for hot coining inserts which were run to higher temperatures. Decarburization was minimized by using a furnace atmosphere of nitrogen and pine oil, and the forgings were also coated with "Aqua-Dag", a suspension of colloidal graphite in water. These procedures were quite effective in minimizing decarburization, according to Boeing, who subsequently tested the 51 production-type forgings made by Ladish.

At the ultra-high strength levels (260,000 to 280,000 psi.) to which 4340 is treated, the minor decarburization level of 0.002 to 0.0025 in. did not act to limit the fatigue strength. In fact, an improvement in fatigue strength was reported. The forgings also had adequate dimensional precision. On the whole, the Ladish phase of the research was considered a success.

High-Speed Techniques

Meanwhile, Steel Improvement and Forge Co. was investigating high-speed forging techniques with an impacter*. Since it was thought that metal would flow through thin sections at high speeds if heated dies were used, the researchers experimented with dies made from a material which could withstand a high temperature – René 41. In the preliminary tests, the die blocks (solution treated and aged) were ground flat and used to evaluate lubricants since lubrication at high temperatures was also considered a problem. Three lubricants, all of which contained colloidal graphite, were tested.

According to the forger, these tests showed that forging at about 600° F. die temperature with colloidal graphite for lubrication was the most practical method for precision work. Above this temperature, lubrication becomes difficult and dies are more likely to deform to the point where the needed precision cannot be maintained.

As a consequence, Steel Improvement gave up the attempt to forge at high temperatures, and settled on S.A.E. A-2, a high-carbon die steel, for the die insert material. Compared to conventional hot work steels, A-2 has greater compressive strength and wear resistance, qualities which are desired in dies for precision forging.

Early tests indicated that decarburization of the 4340 would exceed the maximum of 0.010 in. required by the program. Since nickel coatings were known to prevent decarburization, they were the subject of some experimental work. The forger found that such coatings were successful for short times, but offered little protection when longer times at the forging temperature were involved. Thicker coatings of nickel did not improve surface protection to a significant degree. When argon (under a constant flow) was used as a protective atmosphere on the furnace, decarburization was limited somewhat. However, it seemed that another approach was necessary.

Therefore, this forger decided to try removing decarburization *after* it was formed rather than trying to prevent its formation. Since chemical milling processes looked quite promising, they were investigated. A literature search indicated that nitric acid would be a suitable agent. It did not "... cause (hydrogen) brittleness, as nitric acid is an oxidizing acid", according to R. R. Tatnall in *Metals & Alloys*, Vol. 19, 1944, p. 172. Tests with the acid proved that chemical milling was practical. About 0.02 in. was removed from the surface every hour, and metal removal was fairly constant in depth over the surface. In actual tests, an average of 0.0082 in. was removed in 25 min. (range: 0.0071 to 0.0091 in.). Since these tests were successful, the forger planned to chemically mill the production forgings to remove decarburization. However, program time ran out before the production run of test forgings for Boeing could be made, but few problems remained at that time.

Heating Dies

The third concept, heating dies to the approximate forging temperature, was not as successful as were the other two methods. The attempt (by Wyman-Gordon researchers) to evaluate heated dies ran into trouble almost from the outset. To begin with, René 41 was selected for the dies because of its excellent strength at elevated temperatures. However, the superalloy also turned out to be extremely hard to machine to precision tolerances. This was especially true for sections with deep and narrow slots. For example, the cutting tool

*See "New Techniques Broaden Forging Picture", by J. H. Jackson and H. B. Goodwin, *Metal Progress*, August 1959, p. 97, for description of impacter. This is a patented tool designed and manufactured by the Chambersburg Equipment Co., Chambersburg, Pa.

used to complete the finish machining would bend away from the metal rather than cutting into it. This would work harden the surface making it even more difficult to machine. Many tools were broken during this effort.

Heating the dies to the required temperature, 1600° F., also was a problem. Induction methods appeared promising, but were abandoned when the high frequencies which were needed could not be obtained at the forging press. Globars were eventually used, but were too brittle to withstand stresses which developed during forging.

Finally, five tryout forgings were produced by the setup; however, none of them was satisfactory as far as required specifications were concerned. Much more research is needed if this approach – heating dies to approximate temperature of forging – is to be a success.

Cast Dies Hold Promise

As a sidelight, the solution to this particular problem might be found in cast die materials. In some recent research conducted at Armour Research Foundation, Inco 713 C turned out to be a highly satisfactory die material since it could be heated to 1600° F. for forging. The dies themselves were cast in molds made from

Simultaneous Hot Forming

MP

Special Report

Modern Tool Materials and Metal Fabrication

Many parts on modern supersonic aircraft such as the Hustler (B-58) are made of alpha-beta titanium alloy, a material which is being used more and more because of its high strength-to-weight ratio at elevated temperature. However, titanium alloys are very expensive. Added to the high cost of raw material is the cost of forming and heat treating to produce accurately dimensioned parts. As a result, all titanium parts used on the B-58 have been carefully studied from a cost standpoint.

As a typical example, a number of nacelle parts were designed to be produced from the RS-140* titanium alloy. We decided to shape most of the parts from solution treated sheet at 1000° F.; the solution treated sheet would possess improved formability and negligible spring back at that temperature. Aging for

*Nominal composition: 5% Al, 2.75% Cr, 1.25% Fe, bal. Ti.

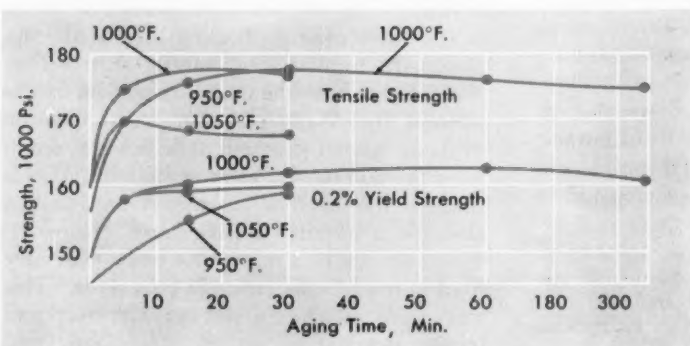


Fig. 1 – Age Hardening Curves for RS-140 Sheet. Note that the highest tensile strength is reached and passed before 30 min.

granulated graphite. This technique gave them a very smooth finish and optimum metallurgical properties. Slots for calrod heating units (needed to maintain the high die temperatures) were also cast into the die bases. According to Paul Gouwens and Andrew Murphy, both of whom were active in the project, the technique was experimental, and precision in forging dimensions was not the primary aim. In spite of this, it seems like a promising technique for making precision forging dies.

However, the close-tolerance program must be classed as an informative and successful project, on the whole. Because of it, much more is known about the possibilities of precision forging. Several promising avenues have been opened for investigation, and dead-ends, not previously apparent, have been exposed.

To sum up, like most innovations, precision forging has its advantages and disadvantages. Admittedly a costly technique, particularly when processing the harder-to-forge metals, its potential is such that many engineers in the forging field have high hopes. Savings can be realized in both material usage and machining. These savings are being made today in areas where competitive procedures also result in high costs. Tomorrow, who can say?

---

and Age Hardening of Titanium Parts

*By R. E. JOHNSON and R. J. McCLINTICK**

Parts made from titanium alloys of the alpha-beta type can be formed and age hardened at the same time by shaping at a high temperature and holding at that temperature for a short period. This technique eliminates the need for long aging cycles and expensive holding jigs. (J27d, Q23q; Ti-b)

6 hr. at 900° F. was then required to produce the highest strength level. Since formed parts had to be constrained in fixtures which were expensive to fabricate and maintain, and extremely long heat-up times were needed, the aging process was quite expensive.

Formability tests showed that parts had to be formed at 1000° F. for up to 30 min. for zero spring back and sharp bends. Therefore, we decided to determine the effect of heating this alloy above the recommended aging temperature of 900° F. We found that the tensile strength dropped 11,000 psi. and yield strength dropped 2000 psi. when the material was heated to 1000° F. for 30 min. for forming. When statistical errors of 2000 psi. (tensile strength) and 2800 psi. (yield strength) are added to the average losses, and the total subtracted from the guaranteed minimum strengths for the aged condition, the design strengths for the finished hot formed and aged part become 167,000 psi.

*Materials and Processes, and Process Control, respectively, Convair-Fort Worth Div. of General Dynamics Corp.

Table I – Thermal Stability of Alloys Exposed to 800° F. for 100 Hr.

Alloy	Aging Cycle	Before Exposure			After Exposure		
		Tensile	Yield	Elong.	Tensile	Yield	Elong.
RS-140 (a)	1000° F., 5 min.	187,700 psi.	162,100 psi.	7.5%	190,700 psi.	165,100 psi.	6.0%
RS-140 (a)	1000° F., 15 min.	186,100	163,200	6.5	190,200	165,300	7.5
RS-140 (a)	1000° F., 30 min.	183,900	162,600	7.5	185,800	163,800	7.0
4-3-1 (b)	1125° F., 5 min.	184,800	171,700	5.8	187,200	175,100	5.3
4-3-1 (b)	1125° F., 15 min.	184,600	171,000	5.3	180,400	165,900	4.0
RS-140 (c)	975° F., 30 min.	188,500	164,100	9.0	184,400	166,800	8.7

(*a*) Republic Steel Corp.; (*b*) Titanium Metals Corp. of America; (*c*) Convair, Ft. Worth, Tex.

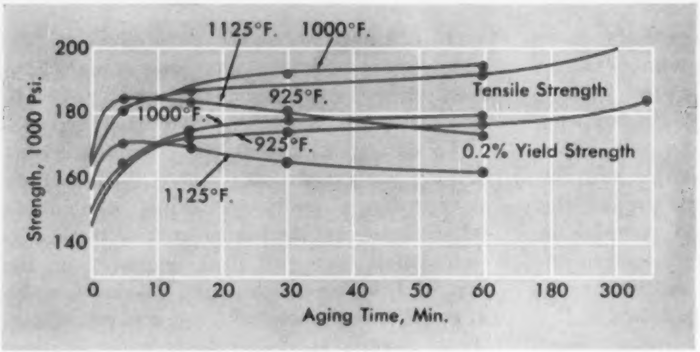


Fig. 2 – Age Hardening Curves for 4 Al, 3 Mo, 1 V Titanium Alloy. This alloy is slightly stronger than RS-140 according to these curves; therefore, the forming and aging temperature is about 100° F. higher

for tensile strength and 145,000 psi. (0.2% offset) for yield strength.

Later, extremely short times (5 to 30 min.) were investigated. As Fig. 1 indicates, near peak aging occurred at 1000° F. in 10 min., and the peak had definitely been reached after 30 min. aging. Therefore, simultaneous hot forming and aging of parts at 1000° F. for 10 to 30 min. appeared possible. If feasible, use of this technique would eliminate the need for an expensive long-time age (up to 10 hr. furnace time per part) along with special aging fixtures.

Tests on four different gages from 0.033 to 0.080 in. (and five heats of material) to determine the difference in strength between the 900° F., 6-hr. age and the short 1000° F., 10 to 30-min. age showed a loss of 14,700 psi. in tensile strength and 4900 psi. in yield strength. When the minimum guarantees for the 900° F., 6-hr. aged material are reduced by the above amounts, the design strengths for the finished parts produced by simultaneous hot forming and aging at 1000° F. for 10 to 30 min.* are 165,000 psi. tensile and 145,000 psi. yield. These values are essentially the same as those for hot formed parts which had been given the 900° F., 6-hr. age.

For proper stability, the room-temperature tensile properties should not drop when the part is exposed to 800° F. for 100 hr. Table I shows that this requirement is easily met with this short-time age. In addition, notched tensile tests showed that the notched-unnotched ratio of RS-140 sheet aged with the short-time cycle is superior to that for material given the 6-hr. age, both before and after exposure at 800° F. for 100 hr. Thus, 6 hr. of aging was not needed from the standpoint of tensile properties, notch sensitivity, or thermal stability.

As an alternate material, Convair requested that the Titanium Metals Corp. of America (TMCA) conduct short aging cycle tests on another alloy, one which contained 4% Al, 3% Mo and 1% V. After these tests were performed, TMCA was able to guarantee 170,000 psi. tensile, 150,000 psi. yield and 3% elongation when the material was aged at 1100° F. for 10 to 20 min. Aging curves for this alloy are represented in Fig. 2.

Since the hot forming temperature required to obtain a sufficiently tight bend radius and eliminate spring back for the 4 Al, 3 Mo, 1 V titanium alloy is about 100° F. higher than it is for RS-140, 1100° F. becomes the optimum temperature for simultaneous hot forming and aging of 4 Al, 3 Mo, 1 V alloy.

Conclusion

These tests show that the 6-hr. age for RS-140 and the 12-hr. age for 4 Al, 3 Mo, 1 V alloys can be eliminated when parts are hot formed under controlled temperatures and time conditions. There is no significant difference in the resulting strength or ductility, and there is also adequate thermal stability for service conditions up to 800° F. for 100 hr.

*To use this combination of forming and aging, we employ a somewhat specialized die design. Dies are made of cast HR-1 Meehanite with steel back-up plates added for more strength. The dies are heated by gas burners arranged differently for each shape of part to insure maximum temperature uniformity. Made of stainless steel tubing (MIL-T-8606), these burners are placed on top and bottom of the Meehanite dies. Titanium blanks are carefully shielded from the gas flame at all times so that the material will not be contaminated by the combustion products. Thermocouples are inserted at strategic points behind the forming surface of the die to help maintain proper forming temperature throughout the part. Although the dies are operated at 1000 to 1125° F., scaling has not been a problem. The Meehanite dies are still in excellent condition after hours of elevated-temperature usage.

Selecting Metals . . .

(Continued from p. 88)

from the corrosion resistance or high-temperature strength of the material; however, it has poor impact properties at ambient temperature. Under repeated shocks of tube cleaning turbines, the carburized case may crack with subsequent rupture of the tube on reheating. Weldability is also impaired.

Steels for chemical plants and oil refineries are rarely selected on the basis of resistance to carburization. The phenomenon occurs largely inadvertently, as the result of some malfunction, upset in operation, or some short-time condition such as localized hot spots during steam air decoking operations or a furnace fire. The heat resistant grades of austenitic stainless steels have improved resistance to carburization. High-chromium steels (27% Cr) have excellent oxidation and carburization resistance; however, their poor creep strength and susceptibility to 885° F. embrittlement preclude their general use. The Incoloy materials are used extensively for fired tubes in ethane heaters because of their ease of fabrication, resistance to sigma embrittlement, oxidation and carburization.

Problems Due to Aqueous Corrosion

A second category of problems in chemical plants arises from the handling of chemicals when in the aqueous condition. As previously mentioned, almost all gases, when dry, can be handled safely in steel equipment. This is also true for practically all dry industrial chemicals. When mixed with water, problems of corrosion may arise, and efforts are made to make the streams compatible with steel. Such techniques as pH and temperature control, inhibition, dilution and equipment design are investigated as means of keeping corrosion of steel at a tolerable rate. When these methods are impractical, protective linings or special alloys are employed.

Hydrogen Blistering

Steel when exposed to certain aqueous corrosive media generates atomic hydrogen, as a result of the corrosion. This permeates the steel, collects in discontinuities such as inclusion stringers or voids and transforms into molecular hydrogen. When a critical amount has collected, pressures are of sufficient magnitude to either raise *(Continued on p. 164)*

Fig. 9 — Groove Corrosion Is Evident Adjacent to Welds in This Pipe Used for 65% Sulphuric Acid

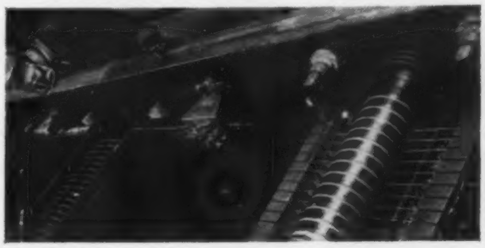
Fig. 10 — Admiralty Brass Tube (Expanded View) Which Has Failed by Stress-Corrosion Cracking. The Tube was in service for 11 months handling steam and condensate plus 5 ppm. ammonia

Can you answer these 4 questions about better plating?

QUESTION:
"How can the solderability of electronic parts be improved?"

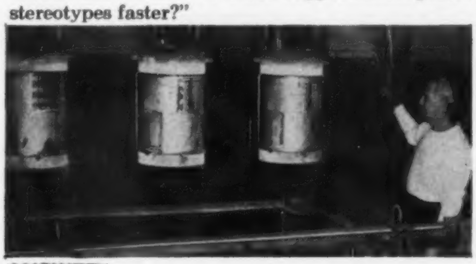
ANSWER:
B&A® Lead-Tin alloys with a high tin content produce non-corrosive coatings of excellent solderability. These coatings are easily soldered on electronic or electrical parts. Solderability is not destroyed by long periods of storage before use. The uniform deposit also helps expedite assembly.

QUESTION:
"How can wire plating be speeded up?"



ANSWER:
The fast plating rate of B&A Copper Fluoborate makes possible high-speed electrocladding of hard, high strength copper deposits on steel wire. For faster electrotinning of copper wire, B&A Tin Fluoborate solutions will deposit tin twice as fast as alkaline baths!

QUESTION:
"What can be done to make rugged nickel-plated stereotypes faster?"



ANSWER:
B&A Nickel Fluoborates build up tough ductile deposits which, in some cases, have enabled stereotypes to run up over 3½ million impressions. They can deposit a nickel face of .0005 inch on the stereotype in 8.0 minute plating cycles . . . providing the high speed operation demanded by the printing industry.

QUESTION:
"What coating will best protect vital engine parts during break-in periods?"

ANSWER:
A lead-tin alloy of low tin content, plated from B&A fluoborate electrolyte, will provide good corrosion and wear resistance as well as superior lubricating properties to protect bearings, pistons and similar parts that require marginal lubrication during break-in periods.

Consider all these advantages of B&A Metal Fluoborates:
No mixing or dissolving necessary (all B&A Metal Fluoborates come in ready-to-use concentrated solution form) . . . easier bath preparation . . . excellent bath stability, with minimum of sludging . . . good covering power . . . give fine grained deposits of good color . . . allow ease of maintenance, since anode and cathode efficiencies approximate 100%.

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Circle 1670 on Page 48-A

CORRESPONDENCE

Granulation of Pig Iron

LONDON

Proper handling of the molten metal from an iron blast furnace has always been a serious problem, even before the turn of the century, when furnaces made only a hundred tons or so of metal a day. Then – and even now in certain places – the iron was run into depressions in a sand bed. The terminology – "pig" for the units and "sow" for the runner – is characteristic. The obvious disadvantages are the labor required to break up and handle the solid iron and the sand which adhered to its surface.

Around the turn of the century, new blast furnaces being built were greatly enlarged in size and capacity, so pig casting machines were devised where a chain belt carrying a succession of steel pans would catch a stream of molten metal. The machine made pigs of uniform size and they could be dumped automatically into appropriate railroad cars.

The usual practice in Great Britain at the present time in an integrated plant is to transport pig iron in its molten state from the blast furnace to the steelworks. If the steel plant does not operate at weekends, the molten iron has to be taken care of, and this is usually done by casting it in a pig casting machine, and stocked for later use. The size of the pigs varies from 20 to 50 lb. and they cannot be handled in bins on account of their size; the charging boxes are filled either by hand or by electromagnet. The transportation of these pigs also causes considerable wear and tear on the handling equipment.

A method has now been developed for granulating the pig iron, which is cheap, results in a product very easy to handle, and apparently has a considerable number of advantages over the older methods. This was devised and patented at the Wellingborough Works of Stewarts and Lloyds, Ltd., and the plant there has now dealt with nearly 1,000,000 tons of iron. The method consists of pouring a ribbon of molten iron over the lip of a runner, into a bank of high-pressure water jets, which splits up the flow of metal into granules, the size of which is to a certain extent controlled by the pressure of water. These granules are collected in the hopper bottom of the granulating tank, and they are continuously removed on an inclined conveyer which can deliver the iron either into trucks or on to a stockpile, depending on local requirements. The nature of the iron is also such that it can be handled through stock bins when desired.

The water from the tank continually overflows so the predetermined temperature in the tank is not exceeded. This overflow water is carried to a settling tank to free it of any entrained solids, after which it can be drained away or it can be cooled and re-circulated if a closed water system is desired.

Such a granulating plant occupies less area than a pig-casting ma-

Stockpile of Granulated Pig Iron With a Pile of Machine-Cast Pigs in the Background. Angle of repose is the same for both classes of products

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Correspondence . . .

chine and considerably less than a pig bed. It also has the advantage of being much cheaper to install than a pig-casting machine. The operating costs per ton are approximately one-third, varying a little depending on the quantity granulated. Less fuel is required in the steel works for re-melting this granulated iron than is needed for the chunky pigs. Maintenance is also reduced to a minimum, the only moving parts being the water pumps and the conveyers. It is necessary to empty the tank about once a week to clean out accumulated sludge.

The basic size of plant is designed to granulate at the rate of two tons per minute, but for larger capacities the plant can be increased by units of one ton per minute each, up to any capacity required.

Tom Bishop
Consulting Editor
Metal Progress

Dangerous Watches on the Loose

Califon, N.J.

Readers of *Metal Progress* may be interested to know how the dangerously radioactive watches of foreign manufacture, noted in the item on p. 134 of the February issue, were discovered.

The St. John Filmbadge Service has been monitoring personnel for radiation exposure in a large metallurgical plant. Only X-ray equipment is in use at that plant and no unpermissible exposures ever occurred. However, an unusual exposure of minor importance was discovered in the course of routine procedures, and the film indicated radio-isotopes rather than X-rays as the source of radiation.

The health supervisor at the plant discovered that the person whose filmbadge showed the exposure was sporting a new wrist watch. We suggested that he place the watch between two filmbadges over night. This produced high markings on the film.

About that time we had two visitors from the U.S. Atomic Energy Commission's staff at our laboratory, and I told them about the radioactive wrist watch. They asked for the

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Correspondence . . .

watch and traced the manufacturer. It was of Swiss origin and the radioactivity was due to strontium 90 and the element was supplied by the British Atomic Energy Establishment at Harwell.

About a month later I noticed a press report from Washington, dated Dec. 17, 1959, stating that 605 watches had been imported to this country by the American Rolex Watch Corp., and a much smaller number probably had been purchased by Americans abroad. So far, about two thirds of them have been returned for new, safe dials. (By the way, the retail price is $240, bracelet and Federal tax included.)

It appears to me that the broader aspects of the case are: Why did the customs inspector pass a shipment of such highly radioactive material? (In lots of 600 the radioactivity could easily have been discovered.) New York City has a strict radiation protection code and the Department of Health is supposed to check all radio-isotope users and places where radioactive materials are stored. Why did they fail to discover this unusually high radioactivity?

HERBERT R. ISENBURGER
President
St. John X-Ray Laboratory

More on "Clean" Steels

PITTSBURGH

In H. W. McQuaid's comments on my paper, "Effect of Melt Shop Practice in Cleanliness for High Speed Steels" (*Metal Progress*, March 1960, p. 174), most of his discussion is related to microcleanliness, while the paper itself was primarily limited to macrocleanliness. However, the paper did identify the slits as being chromite and silicate inclusions. Sulphides were not found to any degree in the steels and they have never been a problem. Except for bearing applications, high speed tool-steels are not purchased to a micro-cleanliness specification.

Mr. McQuaid inquired about the sulphur content in the high speed steels investigated. The average sulphur content was 0.014% but no relationship was found between sulphur content and macrocleanliness. Deliberate additions of sulphur

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Correspondence . . .

(0.12%) are made to high speed steel to increase machinability.

He mentioned that "the adverse effects of sulphides on hot and cold impact values are much more directly related to the type of sulphide than to the amount". However, this investigation was not concerned with the cause of low impact values or hot shortness. The steels were deliberately fractured in order to locate slits, and the presence or absence of slits was the basis for rating macrocleanliness.

Mr. McQuaid also asked about the manganese practice. After the original slag (all heats were melted with a two-slag practice) was reduced and up until 40 min. before time of tap, the steel contained about 0.20 to 0.22% Mn. Then, about five points of manganese was added to the steel as FeMn. (The usual upper limit for manganese in these steels was 0.30%.)

On the surface, the idea of adding an excess amount of manganese silicates, which will rise to the slag, has merit. However, the formation of manganese silicates can only be accomplished under the following conditions: (*a*) The manganese must be in the form of MnO so that MnO combines with SiO_2, and (*b*) since all of these steels contain 4% Cr, a large amount of Cr_2O_3 will be formed before manganese is oxidized. Not only will this method increase the amount of chromite inclusions in the steel, but chromium will be lost to the slag.

Concerning the silicon practice, the steel probably contained less than 0.04% Si after the oxygen blow and up until 20 min. before tap. The required amount of silicon was added as 50% FeSi 20 min. before tap.

The high silica slags were obtained by making deliberate additions of sand or a commercial reducing agent to the refining slag. Deoxidizing with FeSi instead of calcium carbide was another way to obtain a very low lime-silica ratio in the slag. All of these practices, however, produced very dirty steel. The effect of silica content in the slag on macrocleanliness was clearly shown in the paper.

Walther L. Havekotte
Steel Metallurgist
A. M. Byers Co.

PART: Welded bellows-type seal. **MATERIAL:** Type 410 Stainless Steel. **SPECIFICATIONS:** To be hardened under close control because of variations in metal sections. Finished assembly to be clean, bright and free from oxides and scale. Seal in photo has been cut to show cross section of the bellows-type seal.

How would you heat treat a part like this?

The stainless steel bellows-type seal shown is used in a number of applications, from refrigerating systems to missiles, where mechanical seals are needed to resist extreme temperatures from —400F to +1200F. Heat treatment is complicated by the wide variation in section between the thin bellows and the much heavier outer rings.

The Sealol Corporation, Warwick, R. I., solves the problem with a Hayes electric furnace equipped with GLOBAR® silicon carbide heating elements. Depending on the material of the welded bellows (stainless steels of the 300 and 400 groups, precipitation hardened steels such as AM350, 17-7PH, Inconel X, etc.), hardening is between 1700F and 1900F, followed by muffle cooling, both in a hydrogen atmosphere.

GLOBAR elements make possible the precise temperature control and clean heat, independent of the atmosphere, required in this critical operation. Rod-type element simplifies design, furnace construction and servicing. Losses are minimized because all heat is produced and contained inside the furnace.

The many advantages of heating with GLOBAR elements often more than cancel out differentials in BTU costs between electricity and other fuels. Why not investigate with your furnace builder—or write to Refractories Division, Globar Plant, Dept. MP-50, The Carborundum Co., Niagara Falls, N. Y.

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- "On line" operation for many applications—no transformer necessary.
- Rods 4" to 105" in length.
- For greater economy in heat treating, brazing, forging, melting, and sintering.

Circle 1677 on Page 48-A

PERSONAL MENTION

Max Hansen, managing director of Metallgesellschaft A.G., Frankfurt am Main, West Germany – elected a member of the board of directors of Vereinigte Deutsche Metallwerke A.G.

Morton M. Jenkins – from steel sales metallurgist to assistant to the manager of steel sales, A. M. Byers Co., Pittsburgh.

Harold A. Moffat – now salt bath furnace specialist for Lindberg Engineering Co., Chicago.

Robert P. Uhl – from district manager of the New York and Bridgeport territories of Carpenter Steel Co., Reading, Pa., to Atlantic regional manager.

Choh-Yi Ang – now director of the materials laboratories of P. R. Mallory & Co., Inc., located in Indianapolis, Ind.

R. D. Veneklasen – from chief metallurgist and manager of the Niforge Corp., Boston, to supervisor in the metals development department, Thiokol Chemical Corp. Utah division in Brigham City.

Donald T. Smith – named technical sales representative to the New England region of Union Carbide Plastics Co., with headquarters in Boston.

Walter Allan MacLean – appointed inspection specialist, metals and materials treatment processes, by the U. S. Air Force in Boston.

D. H. Blackmar – from LeRoi Div., Westinghouse Air Brake, to chief metallurgist, Talon, Inc., Meadville, Pa.

George H. Bodeen – named general sales manager of all plants of Lindberg Steel Treating Co., Chicago. He is also project manager of the company's rocket and missile department.

Bruce O. Young – from market development coordinator with the alloy and carbon specialties division to product manager, alloy and carbon specialties, Crucible Steel Co. of America, Pittsburgh.

Martin T. McGowan – from development engineer, Bridgeport Brass Co., to staff metallurgist in the pilot production section, Midland (Pa.) Research Laboratory, Crucible Steel Co. of America.

Raymond H. Scheuer – from sales engineer for Midvale-Heppenstall Co. to the Detroit regional sales office of Heppenstall Co. following the merger of both companies' sales force.

Norris G. Yonker – now chief metallurgist at Thor Power Tool Co. in Aurora, Ill.

William M. Dempster – transferred to the Detroit sales office of Surface Combustion Div., Midland-Ross Corp.

Harry M. Weart – left Westinghouse Research Laboratory in Pittsburgh to become assistant professor of metallurgy at Cornell University in Utica, N.Y.

Joseph S. Goughnour – recently retired.

David E. Deutsch – named head of the metallurgy department of advanced projects division, Aerojet-General Nucleonics, San Ramon, Calif.

R. D. Engquist – from senior research metallurgist, American Steel Foundries, East Chicago, Ind., to technical staff, research and development laboratories, Hughes Aircraft Co., Culver City, Calif.

J. R. Lewis – from supervisor, fuel element materials development, aircraft nuclear propulsion department, General Electric Co., Cincinnati, Ohio, to consulting engineer, materials investigation, for the same department.

John T. Rojack – from technician in the metallurgical laboratory to supervisor in charge of wire annealing and plating, Lamson, Sessions Co.

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Personals . . .

Joseph Remenyi – from chief metallurgist, Axelson Mfg. Co., division of U. S. Industries, Inc., Los Angeles, to research scientist in metals for liquid propellant rocket engines at North American Aviation's Rocketdyne Div. in Canoga Park, Calif.

Walter Z. Davis – resigned as director of engineering and research, Brown Trailer Div., Clark Equipment Co. in Michigan City, Ind., to join architectural and engineering firm of Culler, Gale, Martell, Norrie and Davis as partner in charge of mechanical and industrial engineering in Spokane, Wash.

W. L. Phillips – completed his graduate studies at Yale University, receiving a doctorate in metallurgy. Now research engineer at the engineering research laboratory of E. I. du Pont de Nemours & Co., Wilmington, Del.

Marshall G. Whitfield – now president of newly formed Al-Fin Corp., Bethel, Conn.

Malcolm S. Grahm – from project officer in high-strength metals section of materials laboratory of Wright Air Development Center, to Crucible Steel Co. of America's Midland (Pa.) Research Laboratory.

Rocco Robelotto – now research engineer in application resistance welding of high-temperature alloys at North American Aviation in Los Angeles.

Hilton N. Rahn, Jr. – now metallurgical engineer in the physical metallurgy division of Bethlehem Steel Corp.'s research department.

Fred P. Battle – from metallurgist, tin mill division, Kaiser Steel Corp., Fontana, Calif., to metallurgical engineer and plant metallurgist, Union Carbide Ore Co., Newport News, Va.

Francis E. Adams – from Temco Aircraft Corp., to Leukart Machine Co., Columbus, Ohio, heading a department engaged in welding, brazing and heat treatment of alloys used in aircraft and missiles.

Victor Skvara – now working as a metallurgist at Pratt & Whitney Aircraft Co., West Palm Beach, Fla.

309
309S
309SCb
310
314
316
316L
317
317L
D319
D319L
17-4 PH*
17-7 PH*
PH 15-7 Mo*

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Circle 1680 on Page 48-A

Personals . . .

Wayne M. Robertson – completed his master's degree in metallurgical engineering at Michigan State University and is now working for a doctorate at Carnegie Institute of Technology on a National Science Foundation Fellowship.

Fred H. Domina – from research engineer, Boeing Airplane Co., to senior scientist in the missiles and space division laboratories of Lockheed, working on the joining of materials.

Hsun Hu – from Westinghouse Research Laboratories to senior scientist and head of the texture and orientation section, physical metallurgy division, of U. S. Steel's Fundamental Research Laboratory.

Stanley Mocarski – resigned from Ford Motor Co. of Canada Ltd. to become metallurgical engineer with Canadian General Electric, Civilian Atomic Power Department, Peterborough, Ont.

E. J. A. Fontana – now welding laboratory technician in the research laboratories of American Car & Foundry Co., Inc., Berwick, Pa.

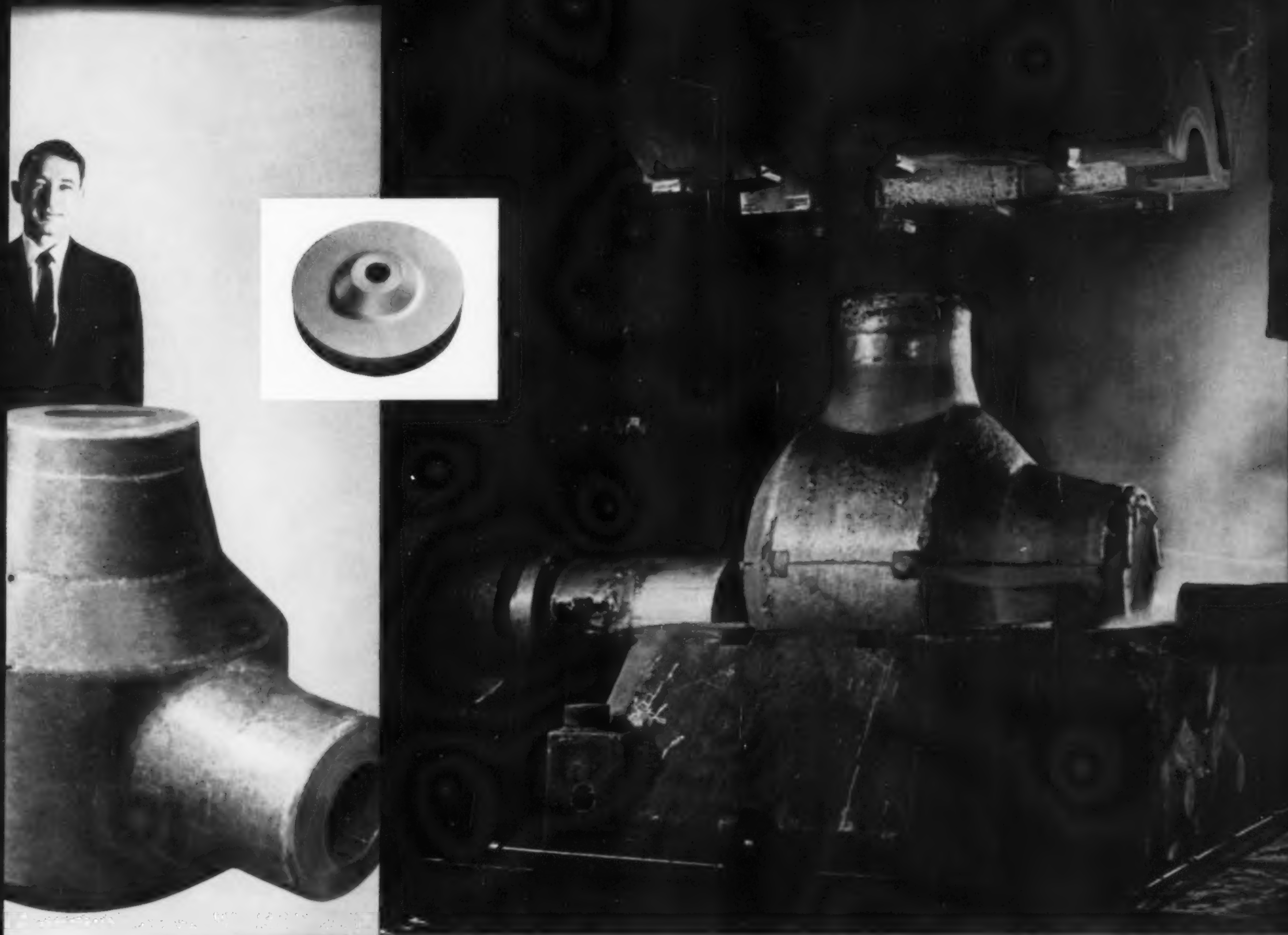
R. Terrence Webster – from senior engineer, Westinghouse Atomic Power Div., to head of fuel element process development group, Aerojet-General Nucleonics, San Ramon, Calif.

Willard H. Nev – from district manager, Pittsburgh, to district manager, Chicago, for Leeds & Northrup Co.

Coy L. Huffine – transferred from General Electric's aircraft nuclear propulsion department to the company's research laboratory in Schenectady, N. Y., for a specialized study of ceramic problems relating to aircraft nuclear propulsion.

Edwin L. Pfeifer – from sales representative in the Pittsburgh district for Heppenstall-Midvale Co. to sales representative in the Chicago district for rolls, forgings, material handling and metal cutting knives.

Andrew R. Walsh – from Wyman-Gordon Co. to metallurgist, high-temperature alloys and technical service, Carpenter Steel Co., Reading, Pa.



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The inset photograph gives an idea of our range in size and shape while producing the same superior properties. This jet engine turbine wheel, A-286 material, weighs about 13 pounds, but is one of today's most demanding applications for a precision member.

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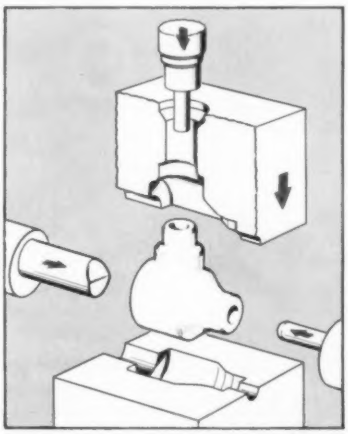

1. Cameron techniques allow intricate shapes to be forged in one heat, yielding uniformly high properties from center to surface and uniform fine grain size.

2. The movement of metal under high internal pressure increases the transverse ductility properties several times above normally expected values.

3. The internal working of the metal breaks up segregated material inherent in the center of steel and high density alloys and yields forgings that consistently meet high ultra-sonic standards.

4. The totally enclosed method of forging avoids flash line magnetic indications and the localizing effect of the flash grain on transverse, fatigue, and stress rupture properties.

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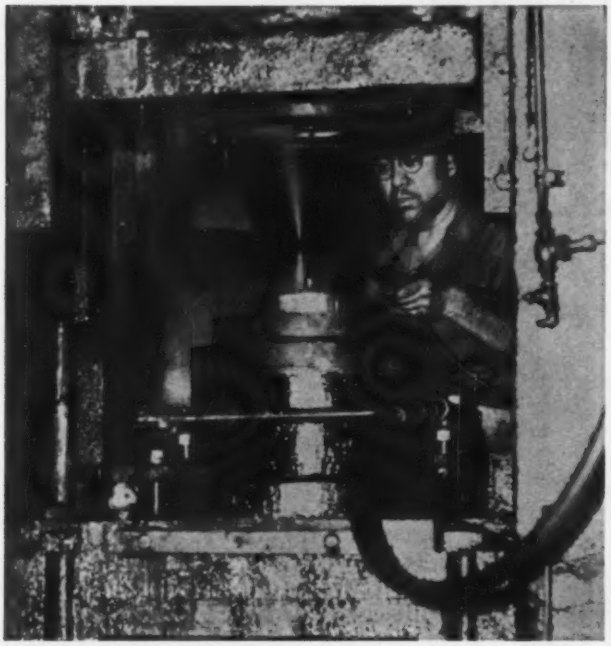
Circle 1682 on Page 48-A

FORGING OR TAPPING . . . 'dag' DISPERSIONS BRING IMPRESSIVE SAVINGS

The versatility of Acheson 'dag' brand dispersions has been proven in many metalworking applications. Here are two such examples: the one involving the material-time savings possible by the use of sprayable colloidal graphite; the other, overcoming pressure and frictional heat problems with the use of a mica dispersion by Acheson.



'Prodag' is automatically spray-applied simultaneously on both upper and lower die surfaces of this forging press at Mueller Brass.

Mueller Brass Company saves $15,000 a year in labor-material costs alone. This is in addition to increasing die life, reducing the scrap loss, and improving the finish of their forgings . . . the reasons why Mueller initially chose Acheson's Prodag® over other forging lubricants. The total savings can be estimated as "considerable", since this Port Huron, Michigan company is the world's largest producer of brass and bronze forgings.

Before using 'Prodag' — a dispersion of graphite and water, Mueller lubricated their crank forging presses with a highly viscous, petroleum-based material which had to be swabbed by hand between each press stroke. The human element frequently meant too much lubricant being applied in some areas of the die, too little in others. The result in the first case, was either imperfect forgings or cracked dies brought about through displacement pressures. In die areas where there was insufficient lubrication, metal stuck in the die cavity. The forged piece had to be scrapped and time was lost while the metal was pried out of the die.

To overcome these multiple problems, Mueller was introduced to a sprayable lubricant and designed their own spray equipment, which lubricates lower and upper dies simultaneously. In this application, 'Prodag' is diluted 1 to 35 with water and is kept under agitation at the press. Time studies have shown that spraying has given them a five percent-per-pound economy over swabbing. Even more importantly, the use of 'Prodag' has resulted in more uniform, complete coverage. The $15,000 to $17,000 annual labor-material savings has, in Mueller's opinion, actually been a "bonus" over and above their original purpose of achieving better forgings and greater die life.

'dag' 242 improves hole tapping operation at General Steel Wares' Montreal Plant

Hole-tapping operations at General Steel Wares, Ltd., Montreal, Quebec, have improved with the application of 'dag' 242 — a dispersion of mica in petroleum oil. So much so, in fact, that an annual savings of approximately $8400 has been realized. The problem was this: broken spud threads during tapping operations on galvanized range boilers, caused a reject percentage of 27%. Fed to the tap as pictured below, the area of the boiler spud was subjected to high pressure and frictional heat. A proprietary type of water-soluble paste had previously been used.

Mr. E. R. Hails, Works Manager at General Steel Wares, found, after detailed investigation of all components involved in the operation, that the lubricant was the key to greater efficiency and fewer rejects. 'dag' 242 was recommended and put into use. Applied by brush to the tap and spuds, this material was immediately effective. The results speak for themselves; from an average life of 3000 spuds per tap, General Steel Wares now averages over 14,000 per tap with 'dag' 242.

Before threading range boiler holes, 'dag' 242 is applied by brush to the tap and spuds.

Perhaps you could be earning similar production economies by using one of the many fine Acheson Dispersions tailored for metalworking use. For further information write for your copy of Bulletin 426 — For Metalworking Applications. Address Dept. MP-50.

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Circle 1683 on Page 48-A

Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Symposium on Atmospheric Corrosion

Digest of four educational lectures presented at the 14th Conference of the National Association of Corrosion Engineers, San Francisco, March 1958: published in *Corrosion*, Vol. 15, October 1959, p. 33-55.

IN THE FIRST PAPER, "Mechanisms by Which Ferrous Metals Corrode in the Atmosphere", C. P. Larrabee began by describing the fundamental reactions. According to theory, ferrous metals corrode because there is a large negative free energy difference (driving force) for the reaction of iron to form iron oxide. The electrochemical theory of corrosion requires a flow of electric current from one part of the metal system (anode) to another part of the metal system (cathode). These electrodes must be in electrical contact with each other (as two areas on a single piece of metal) and joined by an electrolyte which can be water (as a film from rain, droplets from dew, or an absorbed film on a foreign particle). The driving force of this cell is the potential difference between the anode and the cathode.

To complete the picture, electrons which are released when the metal goes into solution must travel through the metal part of the system to the cathode where, in atmospheric corrosion, they combine with oxygen to form water. The ferrous ions, formed at the anode, unite with the hydroxyl ions to form ferrous hydroxide. Ferrous hydroxide, in the presence of air, soon becomes hydrated ferric oxide, the familiar rust.

Iron in air, when clean and dry, becomes coated with an invisible oxide film, but it does not rust. This film has protective qualities; however, high humidity air containing small quantities of SO_2 will cause this iron to rust.

When chromium is added to the iron (as to produce the stainless steels), the invisible surface films formed in air resist rusting in industrial atmospheres. Chlorides in the atmosphere will destroy the protective qualities of these films. Concentration of the chloride is important; for example, specimens of stainless steel located 80 ft. from the seashore become badly stained in three years while those located 800 ft. from the seashore are spotless after the same exposure period.

Sodium chloride and oxides of sulphur are the common pollutants of the atmosphere which cause iron to rust. Depending on the concentration of these pollutants and the compositions of the steels, the iron oxide which forms is more or less protective. That is, the rust may form

Fig. 1 – Effect of Marine and Industrial Atmospheres on Carbon and Copper-Bearing Steels. Plates, 48 sq.in. in area, were used in these tests; "800-ft. lot" refers to distance from shoreline

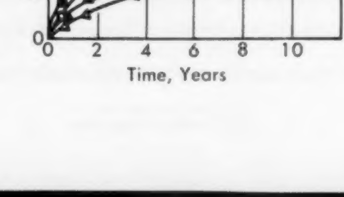
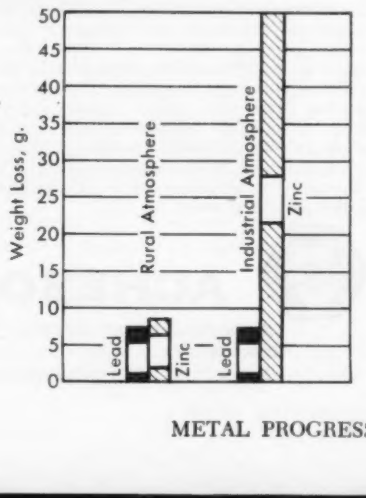


Fig. 2 – Effect of Rural and Industrial Atmospheres on Lead and Zinc. While industrial atmospheres corrode zinc more than rural atmospheres, the resistance of lead is slightly improved. This is because a tenacious film of lead sulphate forms on lead in an industrial atmosphere



Corrosion . . .

rapidly at first, but slow down with time. In the absence of chlorides and sulphates, the amount of rusting is insignificant and that which does form is protective.

Compositions of the steel are important in that small quantities of elements present may have a great influence on the protective nature of the corrosive product. A good example of this is that small quantities of copper in some steels greatly improve their resistance to atmospheric corrosion.

Nonferrous Metals

Theories concerning the corrosion of nonferrous metals were covered in the paper by P. M. Aziz and H. P. Godard, "Mechanism by Which Nonferrous Metals Corrode in the Atmosphere".

As with ferrous metals, moisture and certain pollutants of the atmosphere also control the corrosion of nonferrous metals. Atmospheric water vapor, rain, dew, or mist form the liquid film on such metals. Sulphur dioxide, present in industrial atmospheres, can then react to form sulphuric acid in the liquid film, and corrode the metal surface. Metals such as zinc and magnesium are subject to corrosion by carbon dioxide from the atmosphere which enters the liquid film. Airborne salt is another corrosive agent. Again, as with iron, moisture content of the air is important. The effect of rain is complex since it can either increase or decrease the corrosion on different metals. Wind, sun, and temperature also can play important roles in determining how long a surface remains wet and thereby control the corrosive condition.

Nickel corrodes as a result of simultaneous presence of sulphur dioxide and water vapor when the relative humidity is above 70%, the critical value. The reaction involves sulphuric acid as described above; nickel sulphate is produced and finally basic sulphate results. Rain is beneficial, washing away these hygroscopic corrosion products.

Like nickel, copper is subject to corrosive attack when the relative humidity is above 63%. Again, the final corrosion product is a basic sulphate. This basic sulphate, which contains basic carbonate or basic


Birth of A 20 Ton Sailor

Corrosion . . .

chloride depending on atmospheric conditions, is the so-called "green patina" familiar to all.

Zinc is subject to attack at relative humidities above 70%. It is attacked by acids at rates which decrease with increasing pH. Insoluble basic salts form under certain conditions, and corrosion can be limited by a protective zinc carbonate film.

Aluminum shows excellent resistance to corrosion in the atmosphere because of the oxide film which forms. However, this film can be destroyed by acids that will form from gases such as sulphur dioxide or sulphur trioxide. With time, a new film of hydrated oxide and sulphate of aluminum forms to stifle the corrosive action.

Magnesium corrosion depends on water vapor and carbon dioxide from the atmosphere with the corrosion product being magnesium hydroxide. The hydroxide is believed to absorb carbon dioxide to form carbonate which then reacts with sulphur dioxide to form the sulphate.

Testing in Atmospheres

In atmospheric corrosion work, testing is often a long-term project. In fact, some tests run constantly, as was brought out by H. R. Copson in his talk on "Design and Interpretation of Atmospheric Corrosion Tests". Regardless of the material involved, field testing (the placing of convenient-sized test specimens outdoors) is the most widespread and probably the best method for obtaining information on atmospheric corrosion. Details as to where tests are made, how specimens are designed and mounted, how long the tests are continued, and how the results are evaluated all must be determined.

Test locations are selected to include different types of atmospheres: industrial, marine, rural, urban, suburban and tropical. Results vary greatly, depending on the type of atmosphere; also, conditions vary in the same location from year to year. These atmospheres cause different results on different metals. For example: nickel and Monel are very resistant to rural and marine atmospheres, but are attacked in severe

(Continued on p. 158)

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Circle 1688 on Page 48-A

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This group of special alloys, each having distinct characteristics and advantages, are available in rod form in many sizes and shapes as well as forgings.

CHARACTERISTICS AND APPLICATIONS	ALLOY NO.	NAME	TEMPER
TUF-STUF® ALUMINUM BRONZES AND NICKEL ALUMINUM BRONZES have great strength characteristics. All are more resistant to corrosion cracking under load than copper-zinc alloys and, in addition, some are heat-treatable. They can withstand heavy pounding and have proved excellent for such parts as gibs, cams, valve seat inserts, shifting forks and propeller hub cones.	224E-30	"Tuf-Stuf" Aluminum Bronze	BRINELL 1000 KG load 165
	224E-75	"Tuf-Stuf" Aluminum Bronze	BRINELL 1000 KG load 175
	224C	"Tuf-Stuf" Aluminum Bronze	BRINELL 1000 KG load 185
	224H	"Tuf-Stuf" Aluminum Bronze	BRINELL 1000 KG load 200
	224K	"Tuf-Stuf" Nickel Aluminum Bronze	BRINELL 3000 KG load 250
ALUMINUM SILICON BRONZE is free turning; has high strength, is corrosion resistant and non-magnetic and resistant to corrosion cracking under load.	802	Aluminum Silicon Bronze	ROCKWELL-B 75
600 SERIES® FORGEABLE BEARING ALLOYS range from high strength to low leaded ductile. All are corrosion resistant, free cutting, can be used with hard or soft mating members and can be soldered. They are employed in a great variety of applications ranging from pump gears and valve stems to pinion shafts and transmission rings.	600	Forgeable Bearing Alloy	ROCKWELL-B 88
	601	Forgeable Bearing Alloy	ROCKWELL-B 87
	602	Leaded Forgeable Bearing Alloy	ROCKWELL-B 87
	604	High Leaded Forgeable Bearing Alloy	ROCKWELL-B 86
	605	Low Leaded Forgeable Bearing Alloy	ROCKWELL-B 80
MANGANESE BRONZE ALLOYS are exceptionally strong, tough, resistant to shock and corrosion. Good for screw machine products and forgings for aircraft parts.	241A	Manganese Bronze A	ROCKWELL-B 85
	721	Manganese Bronze High Tensile Grade B	BRINELL 1000 KG load 200
TELLURIUM COPPER has very high electrical and thermal conductivity combined with good corrosion resistance and machinability. Excellent for electronic components.	799	Tellurium Copper	ROCKWELL-B 45

NOTE: The values shown are average values normally obtained in production. Variations must be expected in practice. The values should be used as a general guide rather than the basis for specifications.

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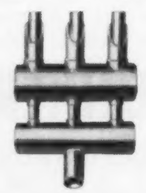

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Circle 1689 on Page 48-A

Corrosion . . .

industrial atmospheres; zinc and lead are quite resistant to rural atmospheres, but of these only the zinc is affected by industrial atmospheres containing sulphur compounds. In some marine environments, nickel is more resistant than copper, but the picture reverses in some industrial atmospheres. Furthermore, alloying additions alter the corrosion resistance of these materials.

Mounting is important. The usual method is to mount 4 × 6-in. specimens between porcelain insulators and expose them at a 30° angle from the horizontal and facing south. Similar exposure racks should be used if results are to be compared. Sheltering from rain, sun, and the like must be considered just as the top and bottom sides of the specimens and edges (particularly the low edge) represent important variable. The types of attack (pitting or general) vary. Attack is usually greatest at crevices. Often it is necessary to simulate actual service conditions to test effects of shelter, crevices, drainage areas, specimen size and shape, and other factors. Other studies involve galvanic corrosion, stress - corrosion cracking,

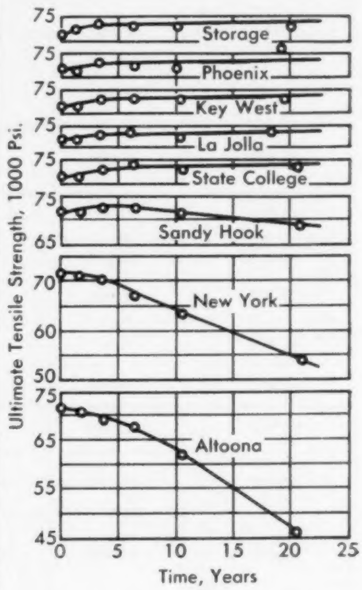


Fig. 3 – Effect of Rural and Industrial Atmosphere on Tensile Strength of Nickel

Corrosion . . .

abrasion, and protective coatings.

Reproducibility of tests is also checked. Weather conditions at the start of a test may have a great effect on the test results. One method to check data is to determine weight loss curves on specimens started on different dates. Control panels are often used each time a test is started to check the initial corrosion conditions for that period. Statistical considerations are also involved. The number of specimens depends on the nature and purpose of the test.

The duration of a test is very important since many materials may show a relatively high rate at first, but protective corrosion products may then largely restrict further attack. This is common for highly alloyed steels. Many of the important effects may not be obvious in the first year or so. Therefore, atmospheric corrosion tests run for as long as 10 to 20 years, some even longer. Except for special situations, there are no accelerated tests for outdoor atmospheric exposure.

Evaluation methods of test results should be worked out before the testing program so as to design the experiments properly. These methods may involve appearance ratings, weight losses, pit depths, and losses in strength, all of which would depend on the purpose of the particular tests. For example, appearance is of prime importance in decorative surfaces. Weight changes are readily made without destroying the test specimens. In some instances electrical resistance can be used to measure corrosion of wire or strip specimens. When pitting is encountered, pit depth must be determined. In all instances, analyses of corrosion products provides valuable information on the corrosion process. Tensile strength and pit depth are generally evaluated on aluminum alloys. By coupling all of the measurements and observations, a rather complete story may be obtained. Due to the time involved in running a test, one should evaluate the results as completely as possible—20 years is a long time to wait for another specimen if an important measurement is neglected.

The last paper in this educational series was "Deterioration of Materials in Polluted Atmospheres". John

Corrosion . . .

E. Yokum, the author, described the effects of specific atmospheric pollutants on nonmetallic materials. Air pollution conditions vary from simple single pollutants to complex situations involving many pollutants. Topography and wind movement have a great influence on the concentration of the pollutants.

For example, sulphur dioxide and sulphur trioxide can attack carbonate-containing building materials such as limestone, slate, marble, and mortar. Leather, paper, textiles (such as cotton, wool, nylon) are damaged. Carbon dioxide can be responsible for the deterioration of carbonate-containing materials such as limestone. Hydrogen sulphide affects lead-containing paints. Hydrogen fluoride is an extremely dangerous and corrosive gas. It attacks many metals, glass or enamels. Smogs having high ozone levels are associated with severe deterioration problems. Rubber, elastomers, textiles and dyes fall in this group.

Solid particles vary in identity and may deposit on surfaces with little or severe damage resulting depending on the reactivity of the substance in its environment and the material on which it is deposited. Corrosion damage to automobiles is a good indication of the corrosiveness of the atmosphere. Finally, moisture and humidity play a major role.

F. H. Beck

Vapor-Degreasing . . .

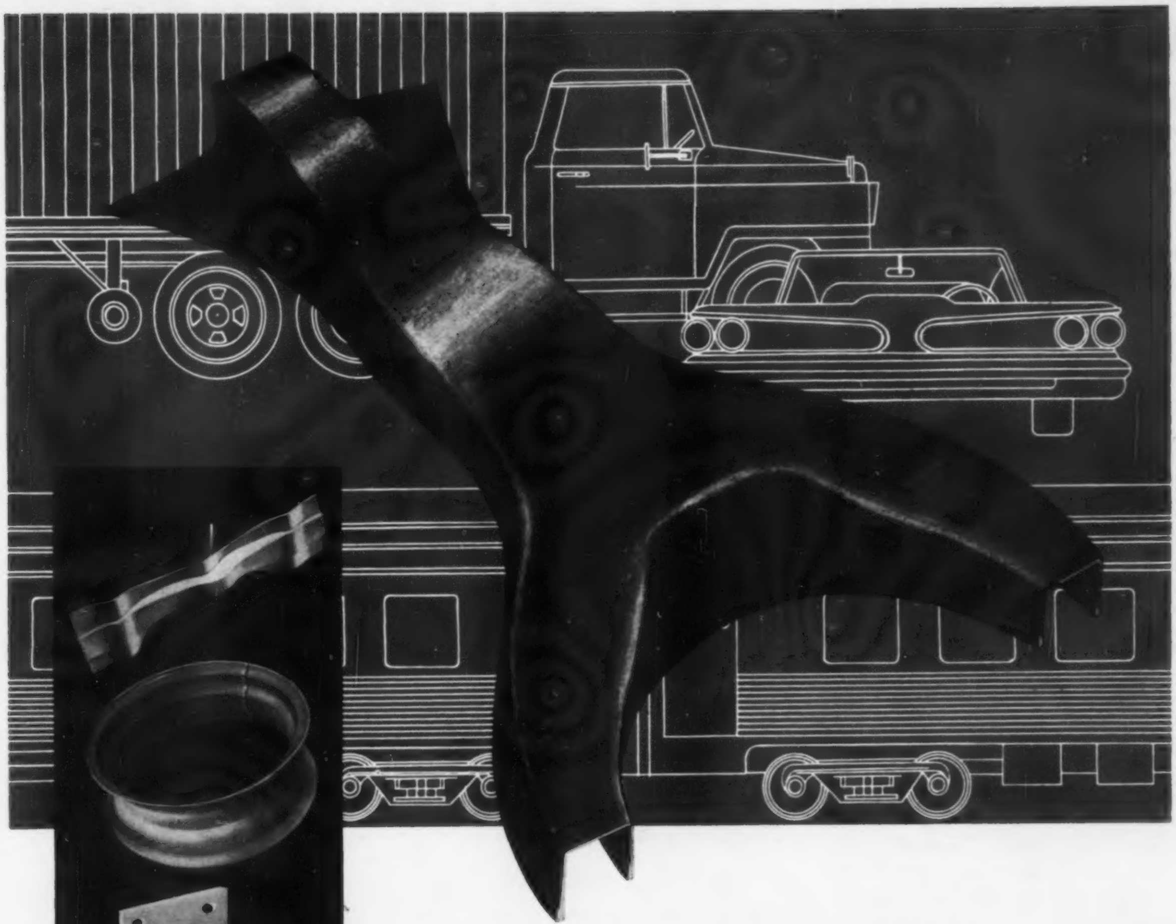
(Continued from p. 96)

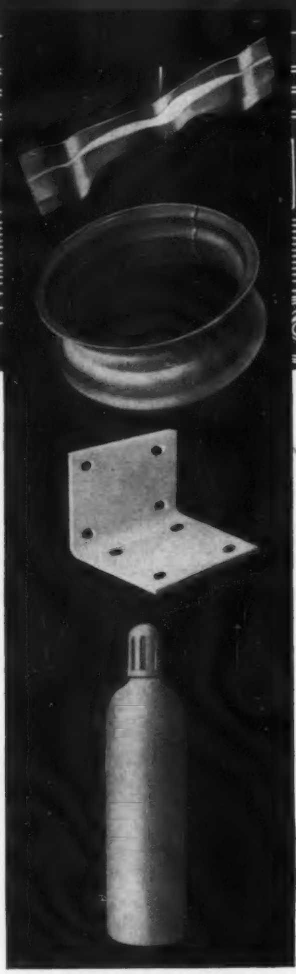
ing jobs require individual study and analysis if the best method is to be chosen. This means that one cannot give specific answers which apply to a wide variety of degreasing problems. However, some of the better recognized and more generally applied good practices that minimize or eliminate plant troubles can be presented.

First of all, stay within the operating limits of your equipment. If a particular solvent is specified for a vapor degreaser, only that solvent should be used. Before making major changes in a cleaning operation, check with a qualified equipment or solvent supplier for recommendations. Where operating temperature is specified or limited, it should not be exceeded.

Do not neglect maintenance. All equipment requires attention, and degreasers are no exception. Safety control instruments on degreasers are essential, too. They must be properly installed and periodically checked. If an exhaust system is required, it must be properly designed and installed, or it may create rather than solve a problem. It is also important that the people who operate and maintain degreaser equipment be adequately informed and trained. Free instruction on solvents and equipment can be obtained from suppliers of these items.

Avoid introducing strong mineral acids, alkalis, oxidizing agents or cyanides into degreasing solvent. They may react with or degrade the solvent. Acids can also cause corrosion of equipment and parts. Solvents which react with water (hy-





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Vapor-Degreasing . . .

drolyze) require special care and equipment design. During operation, the solvent should be checked by one or more simple control tests, such as pH measurement or titration for acidity or alkalinity (Table II, p. 95). Changes in properties of solvents can be expected during use even though parts are being satisfactorily cleaned. However, any marked change from the value shown for a new solvent should be investigated.

The most expensive item in vapor degreasing is the solvent cost, whereas in aqueous cleaning, chemicals average only 20% of the total cost. Thus, a cursory analysis of cleaning expense on the basis of chemicals alone is very misleading. It does not take into consideration water, power, steam, gas, sewage, maintenance and other miscellaneous expenses that are often charged off to other departments in the plant despite the fact that they are very real costs of cleaning. Management is interested in true operating expense of each operation in a plant. Therefore, cleaning costs must be evaluated on this basis.

Table III, p. 96, compares expenses of aqueous and solvent degreasing in a job for which both methods have proved satisfactory. In this instance solvent degreasing offers substantial cost savings. A less obvious advantage is that of water disposal. Water leaving the degreaser is uncontaminated and can be used in other operations; disposal of emulsion is to a sewer. Antipollution treatments would mean additional costs.

Another potential saving occurs if the parts must be absolutely dry. Blowoff in the washer cycle removes most but not all water from the parts whereas vapor degreasing leaves them completely dry.

Cold Extrusion . . .

(Continued from p. 124)

from 1 to 5 in., and lengths up to several feet are feasible.

Recent developments in nuclear power-plant technology have created a substantial need for thin-walled tubes of columbium and tantalum. These metals work very readily by normal cold tube-reducing and drawing processes. One difficulty, however, has been to obtain tube blanks of reasonable cost. Cold extrusion has proved to be the answer to this problem. Extremely coarse-grained cast slugs melted in electron beam furnaces have been successfully extruded with excellent surface finish and fine-grained structures. Mechanical properties of cold extruded columbium tube blanks are 64,400 psi. tensile, 62,200 psi. yield and 9% elongation. For tantalum these are, respectively, 100,300 psi., 86,400 psi. and 12%.

Quite recently tube blanks of vanadium and beryllium have been cold extruded. The beryllium slugs were sintered powder compacts. They extruded well into precision tubes with excellent surfaces and mechanical properties.

Tube blanks from pure vanadium have also been cold extruded from cast and forged slugs. When annealed, the blanks can be drawn into thin-walled tubes.

Selecting Metals . . .

(Continued from p. 88)

a blister on the steel surface or to crack it internally. The lower quality steels have more inclusion stringers and are more prone to develop blisters than high-quality steels. Appearance of a steel vessel affected by hydrogen blistering is shown in Fig. 8 on p. 88.

Attack of this type is quite rare; it is found principally in gas treating plants where large amounts of hydrogen sulphide are present. The problem is ordinarily handled by chemical methods by changing the composition of the components which develop atomic hydrogen. Occasionally, it has been advisable to install a sacrificial steel liner inside a pressure vessel. Blistering occurs on the liner without damaging the outer shell.

Galvanic Corrosion

Galvanic corrosion is the preferential corrosion of a metal in an electrolyte when potential differences exist between the metal and some other substance. Corrosion occurs on the surface which is the most anodic. The greatest source of

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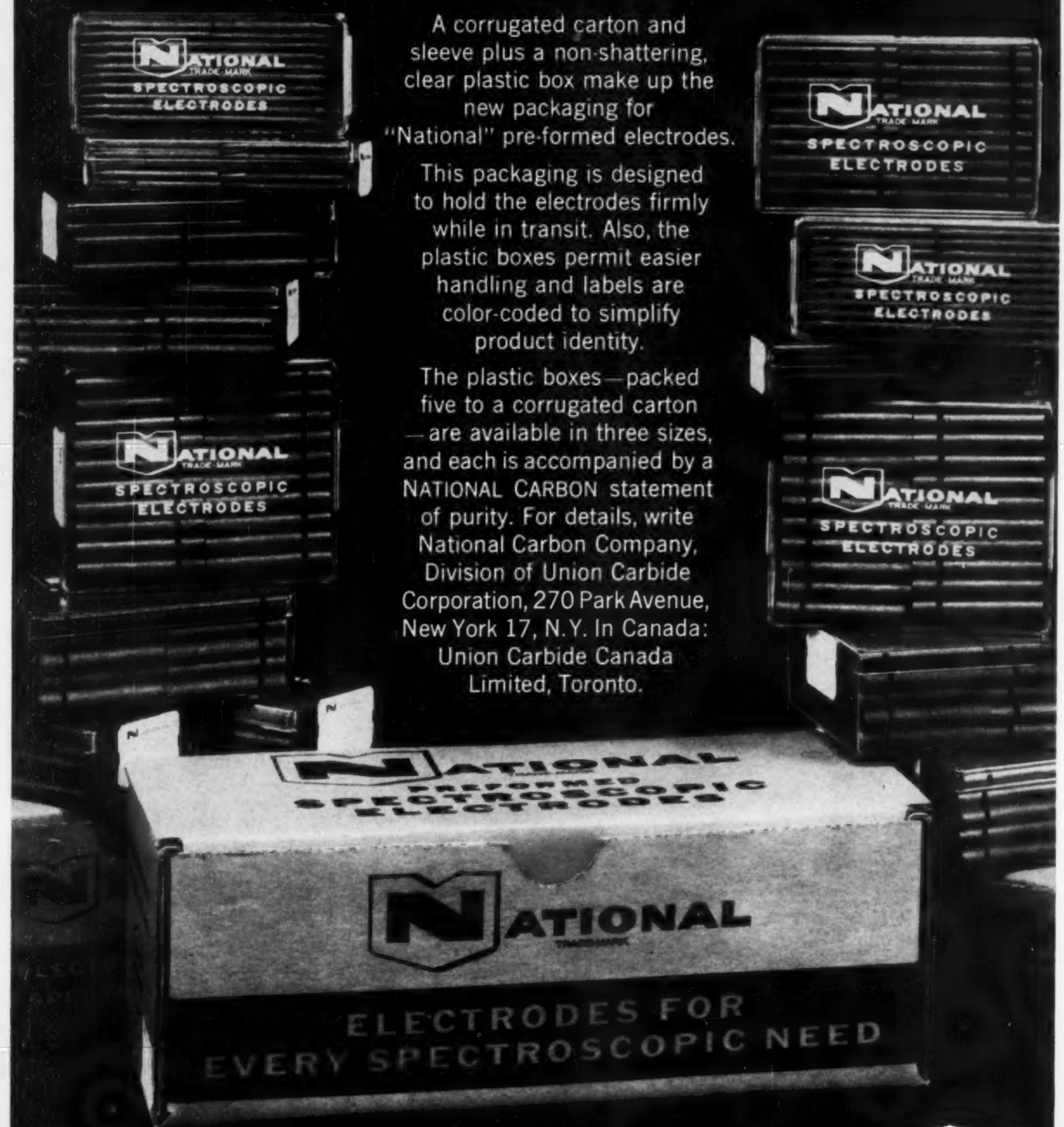

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Circle 1697 on Page 48-A

Selecting Metals . . .

trouble is on underground piping and the lower surface of storage tanks. In these spots, different soils set up electrical potential differences which create selective corrosion of the steel. This problem is handled by wrapping of pipe with asphaltic materials or cathodic protection. Sometimes both are required. Tankage should be designed with good drainage to prevent accumulation of water on the under side.

Intergranular Corrosion – Austenitic stainless steel which has been sensitized is subject to galvanic attack of its grain boundaries. Sensitization results when stainless steel of the 18-8 Cr-Ni type is heated in the range of 800 and 1600° F. This produces an intergranular precipitate of chromium carbide which depletes the adjacent grain boundary area of chromium.

This phenomenon is well known in the chemical industry, and to prevent it the stabilized grades, Types 321, 347 or 304 L, are required in critical services. Type 304 is used only in noncritical services or in furnace piping where the metal is not exposed to aqueous environments. In the latter instance, care is taken during shutdown periods to insure that the temperature in the furnace does not drop below the dew point. However, failure of Type 304 by intergranular corrosion has been caused by condensed flue gases containing SO_2.

Intergranular corrosion is not confined to stainless steel. It can also occur in Hastelloy B in chloride service and to nickel in glycerine-organic chloride mixtures at high temperatures.

Groove corrosion is galvanic corrosion which preferentially attacks heat-affected areas of steel equipment when exposed in certain corrosive media. When steel is heated, as in welding, a narrow band of a spheroidized structure is formed adjacent to the weld. In certain electrolytes, this zone is anodic to the parent metal and a high localized rate of attack occurs. Appearance of these grooves in a welded steel elbow which had been handling strong sulphuric acid is shown in the photograph on p. 134 (Fig. 9). Grooving corrosion has also been noted in plants handling strong caustic, furfural, and hot phenol.

The remedy is to normalize the parts after welding. This treatment reabsorbs the sensitive area and the entire piece is uniform in structure.

Dezincification is a type of galvanic corrosion in brasses containing more than 15% zinc. In the presence of an electrolyte, dezincification is created by the alloy going into solution followed by a redeposition of porous copper which has very little mechanical strength. There are three types of dezincification – intergranular, layer and plug. The latter is the most serious.

Dezincification is most common in brass condenser tubes when exposed to water services. The problem is controlled largely by the addition of inhibitors, such as arsenic, phosphorus or antimony, in small amounts to admiralty brass. Cooling tower hardware is subject to this attack and care should be taken to install

(Continued on p. 172)

Superex is easily combined with other insulations such as Johns-Manville Thermobestos®, J-M 85% Magnesia or J-M Insulating Fire Brick.

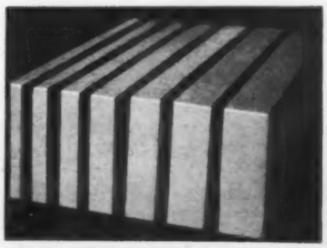
Only Johns-Manville Superex insulation performs 3 ways better at high temperature!

Few industrial products are so outstandingly superior, or so widely used in their area of application, as Johns-Manville Superex® Insulation.

A block insulation formulated of diatomaceous silica and asbestos for furnace and other applications, Johns-Manville Superex brings many advantages to high-temperature service—each contributing to reduced construction, maintenance and operating costs.

Superex is installed with measurable savings in time and labor! It is easy to cut and handle . . . weighs only 2 lbs. per sq. ft. per inch thickness . . . available in a wide variety of large block shapes and sizes. At high temperature—the material's excellent insulating value, thermal stability and resistance to shrinkage keep fuel costs low. Equally important—Superex saves on maintenance, too . . . easily withstands the daily abuse of normal service.

Send for your copy of IN-190A, the 12-page design and technical data brochure. It lists suggested applications—gives complete heat transmission tables and performance data. *Write for it today.* Address Johns-Manville, Box 14, N.Y. 16, N.Y. In Canada, Port Credit, Ont.



Saves waste. Superex comes in 7 standard thicknesses from 1" to 4". Other sizes available on order.

JOHNS-MANVILLE

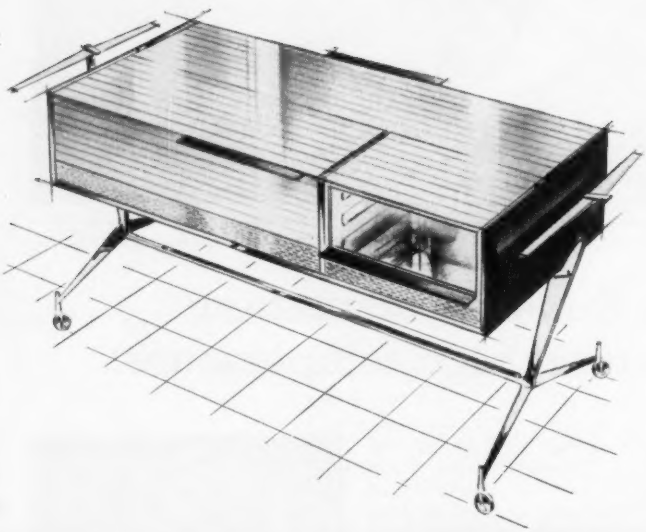
JOHNS-MANVILLE JM PRODUCTS

Circle 1700 on Page 48-A

Carl Sundberg and Montgomery Ferar joined fortunes in 1934 and since have had a great influence on improving the design of mass-produced consumer and industrial products.

One of the largest of the nation's recognized design firms, they have put their talents to work on hundreds of nationally known products ranging from pencil clips to heavy-duty motor trucks and electronic computers. Recognized leaders in the design of electrical appliances, they are permanently retained by many of America's best known appliance manufacturers.

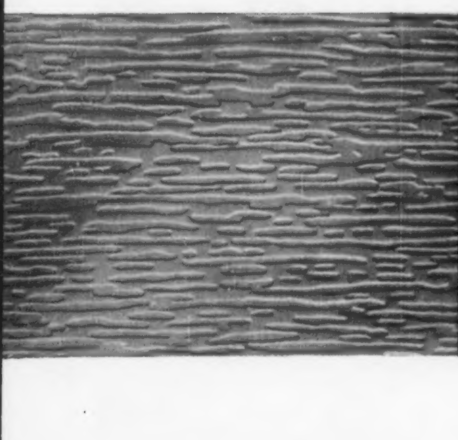
Sundberg-Ferar designs a unique, portable kitchen caddy with wonderful . . .

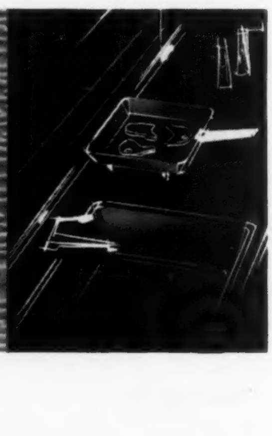


• Sharonart® is truly the designer's metal. Evidence of this fact is this modern kitchen caddy designed in Sharonart® by Sundberg-Ferar, one of the oldest, largest and most successful industrial design firms in the United States.

The portable caddy permits complete cooking facilities anywhere inside or outside of the home. To make sure it would be able to absorb the punishment of daily use, yet stay bright and clean, Sundberg-Ferar designed the cabinet and working areas in patterns of Sharonart® Stainless. Wood grain Sharonart® steel panels at each end give the furniture-look that blends with other home furnishings.

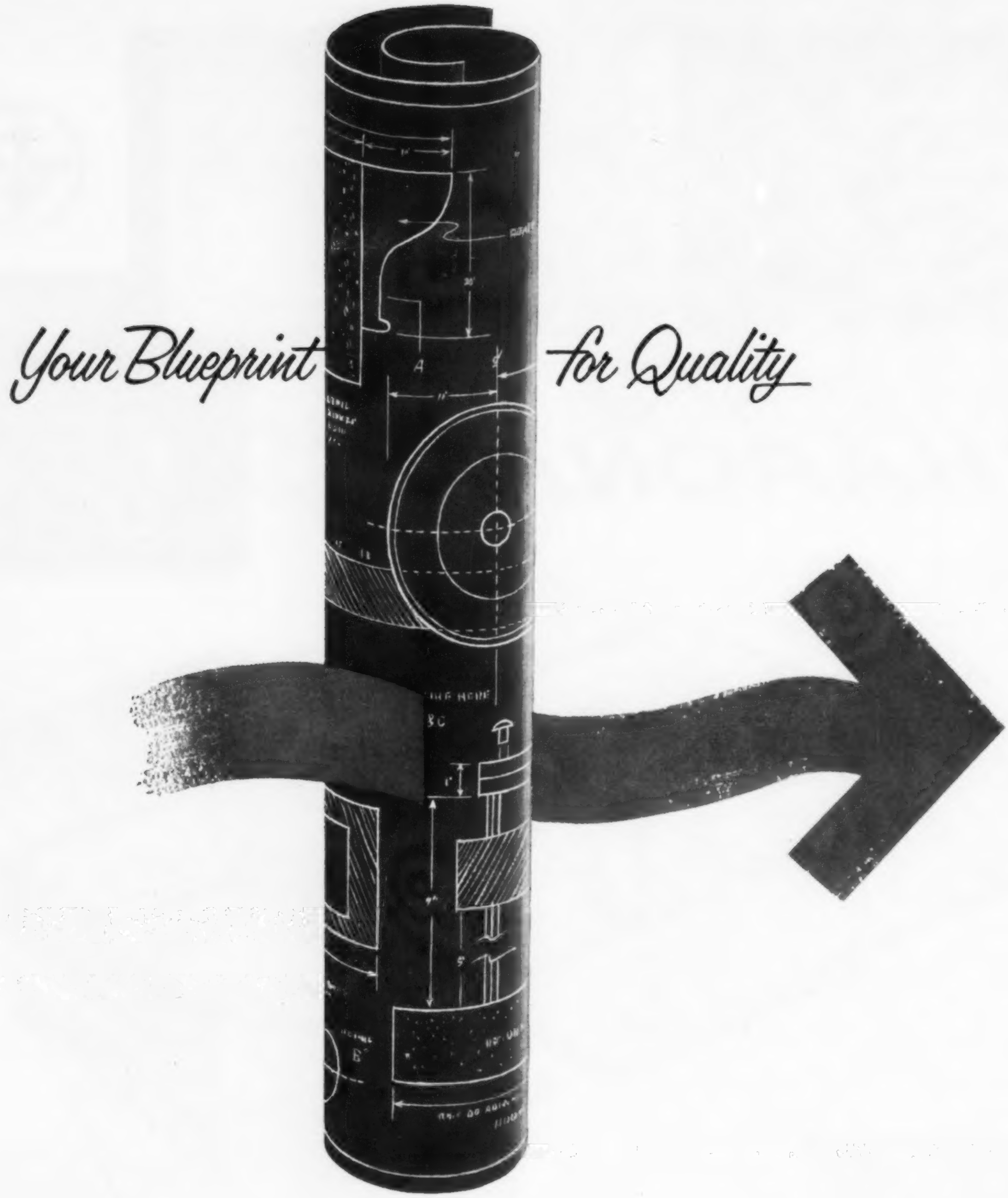
The textured beauty of Sharonart® can be produced in an almost limitless number of patterns. This permits easy model changing. It's easy to clean and will not show wear. It can be painted, plated, or vinyl coated with beautiful results. Is it any wonder that more and more of the leading designers are turning to modern Sharonart® for modern product design? *Sharon Steel Corporation, Sharon, Pa.*





About the portable kitchen caddy: This is a design only, produced to show the tremendous utility of Sharonart®. All the seemingly built-in utensils are self-energized, and can be plugged into any electrical outlet as well as being used with the caddy itself. The rotisserie has vertical elements that can be moved closer together for the smokeless vertical broiling of steaks. All utensils are removable and can be used at the dinner table for gourmet cooking. Plenty of workspace is provided for complete meal preparation right at the caddy.


Steel
SHARONART®
SHARON Quality STEEL
Circle 1701 on Page 48-A
SHARONSTEEL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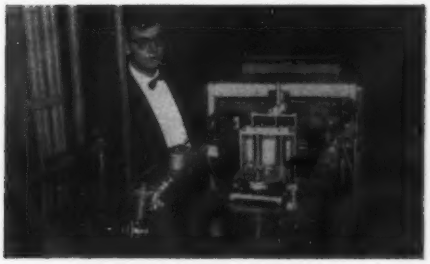

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TRIPLETT & BARTON
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SONOFLUX
Magnetic Particle Systems

SONOFLUX brings to Sperry a complete new line of magnetic particle inspection equipment, both standard and special order, as well as services and a full line of supplies. Here a crankshaft is being checked for fatigue and stress cracks at the overhaul plant of an engine re-builder.

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MAGNETIC PARTICLE

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Sperry Products Company
DIVISION OF HOWE SOUND COMPANY
505 Shelter Rock Road, Danbury, Connecticut

Circle 1702 on Page 48-A

Selecting Metals . . .

red brass or silicon bronze, which are not subject to dezincification.

Under the combined effects of sufficient residual tensile stress and exposure to a critical corrosive environment, almost any metal can be made to fail by stress-corrosion cracking. Corrosion in this instance, as measured by loss in dimensions, is usually negligible. Chloride solutions are the worst offenders in promoting stress-corrosion cracking of stainless steel. Caustic and nitrate solutions will crack steel if concentrations and temperatures are critical. Mercury and ammonia will readily crack strained brass.

The mechanism of stress-corrosion cracking involves a complicated sequence of corrosion and fracture. It has been shown that fine pitting is needed to start the activity. The pit initiates a mechanical crack at a right angle to the maximum strain, which progresses until the material fails completely. A brass tube which has failed as a result of stress-corrosion cracking is shown in Fig. 10 (p. 134).

To avoid stress-corrosion cracking, the present practices are to stress-relieve the equipment by thermal treatment or to use a material which is not subject to cracking in the particular environment. Data obtained from exposure of stressed specimens to the pilot-plant streams are used as criteria for specifying stress-relieving treatments. Due to the wide use of sodium hydroxide, much experience has been gained and predictions can be made as to the critical area where stress-corrosion cracking (known as caustic embrittlement) will occur, and appropriate stress-relieving can be specified.

Corrosion fatigue may be encountered when equipment such as condenser tubes is vibrating in the presence of a pitting type of corrosion. A crack starts at the base of a small pit and proceeds in a straight path similar to ordinary fatigue. Vibration prevention or use of a more resistant metal is the usual cure.

The chemical industry is restricted by a narrow zone of temperature where present materials can operate. The limit for commercially available metals is between -450° F. and about 2000° F. Linings of nonmetallics may extend the upper limit by

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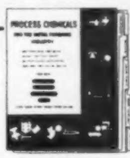

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Circle 1704 on Page 48-A

Selecting Metals . . .

a few hundred degrees. However, there are reactions for producing many interesting compounds which require temperatures of several thousand degrees, at the same time being under high pressure.

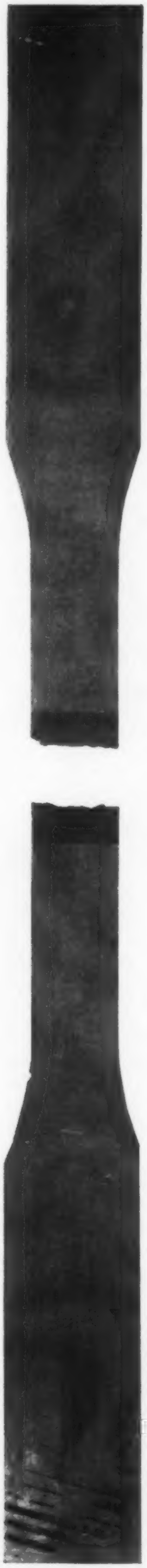
The newer alloys and coatings being investigated by the jet aircraft and missile industries offer encouragement and may furnish some of the answers.

Stainless Steel-UO_2 Plate

Digest of "The Fabrication of Stainless Steel-UO_2 Fuel Plates", by W. R. Weinberger and H. S. Kalish. Paper presented at the Nuclear Engineering & Science Conference, Chicago, March 1958.

THIS PAPER describes fabricating techniques employed in preparing atomic reactor fuel elements containing a dispersion of UO_2 powder within a stainless steel matrix. The basic procedures had previously been developed at Oak Ridge National Laboratory. The fuel core was prepared by blending a UO_2 powder of suitable particle characteristics (which are not explicitly stated) with either Type 304 or Type 347 stainless steel powder in mixtures ranging from 18 to 30 wt.% UO_2. Compacts pressed at 100,000 psi. possessed satisfactory green strength for handling and assembly; sintering prior to assembly within cover plates was found to be superfluous. Uniformity in UO_2 distribution was obtained only with stainless steel powders having a particle size of −325 mesh. Radiographic illustrations also suggest that UO_2 of −325 mesh size, while less important, contributed to somewhat better uniformity. (Apparently no attempt was made to measure or assess the effects of UO_2 particle size variations in the range of 1 to 40 microns).

The core was jacketed (by the picture-frame technique) with cover plates of either Type 304 or Type 347 stainless steel. An attempt to minimize material costs by using strips in place of a punched frame was unsuccessful in achieving joints that were oxide-free. Solid picture frames which were welded along all edges to the enclosing cover plates, were satisfactory but spot welding was less expensive and quite adequate if the first hot reduction in rolling was at least 30%. The forming procedure after assembly involved preheat, hot rolling, annealing, cleaning and cold rolling to final thickness to provide plates 0.030 × 2.778 × 23 in., containing cores 0.020 × 2.54 × 22 in. A hot reduction of about 30% per pass was most satisfactory using a rolling temperature of 2100 to 2155° F. for Type 304 and 2190 to 2230° F. for Type 347. Annealing was done in dry hydrogen (dew point not stated) at 2100° F.; this reduced some but not all of the surface oxide formed in rolling. An acid pickle removed the remaining oxide. Final cold rolling employed reductions of 0.001 in. in thickness per pass to minimize camber and maintain flatness. Where the total cold reduction was 20 to 25%, the rolling could be done without interruption, but for reductions of 40% or more, an intermediate anneal was essential. After cold rolling, the plates were annealed by



Weld failures cut 89% using vacuum-melted filler wire

[*Weld tests on alloy steel wire used in missile applications revealed nine times as many failures with air-melted wire as with Cannon-Muskegon vacuum-melted wire.*] [*Superior to consumable-electrode melting, Cannon-Muskegon vacuum-induction melting greatly reduces gas levels (nitrogen less than 25 ppm, oxygen less than 25 ppm, hydrogen less than 5 ppm). Combined sulphur and phosphorus run less than .015%.*]

[*These remarkably low gas and impurity levels can be most efficiently obtained with Cannon-Muskegon vacuum-induction melting. You are invited to write Cannon-Muskegon for further details.*]

Among test samples prepared from air-melted wire, 18 out of 32 failed at the weld.]

Among similar samples prepared from the vacuum-melted wire of the same grade, only two out of 32 bars failed at the weld.]

[*Different alloys of Cannon-Muskegon vacuum-melted welding wire are available in sizes from 1/32" to 1/8", in 36" cut lengths, or in 10 or 25-lb. spools packed in airtight Argon-filled steel containers.* ]

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Circle 1706 on Page 48-A

Stainless-UO_2 Plate ...

stacking alternately with 0.030-in. thick stainless steel plates coated with levigated alumina, and heating to 2100° F. for 45 min. in dry hydrogen (any intermediate anneal followed the same procedure). Finally, the plates were trimmed to specified length and width.

Photomicrographs of longitudinal and transverse sections at 100 × show reasonable uniformity of UO_2 particle distribution, but reveal moderate stringers in the rolling direction. A procedure involving a multiple-cavity picture frame enclosing several parallel cores to permit a square plate assembly that would be amenable to cross rolling would be worth considering to minimize this stringering effect.

J. A. Fellows

Grinding Titanium With Belts

Digest of "Belt Grinding of Titanium Sheet and Plate", by Carl T. Olofson, Defense Metals Information Center Memorandum 11, March 15, 1959, Battelle Memorial Institute, Columbus, Ohio.

When compared with common metals, titanium is more difficult to grind with abrasive belts. It reacts with oxygen and nitrogen in the air to harden the metal surface. Also, the metal is likely to weld to the abrasive grains. Successful grinding can be accomplished by lowering the temperature at the grinding point and by controlling "fracture wear" of the abrasive grains so that new cutting edges are constantly produced. Close dimensional tolerances can be maintained; surfaces 36 × 36 in. have been produced with 0.004-in. maximum deviation. The cost of grinding titanium is estimated at six to ten times that of stainless steel.

Silicon carbide abrasives of dense texture give best results under normal feeds, but aluminum oxide is preferred for extremely heavy feeds. Medium to fine grain (40 to 80) is normally used for roughing and spotting operations, extra-fine grain (120 to 220) for finishing. Belt backing may be paper for some dry or oil grinding, but cloth backing is

used for more rugged work. Backing is waterproofed for water-base fluid grinding. Thickness is held to close tolerances.

Contact wheels support the belt, and govern the action and effective penetration of the abrasive grains. Wheels may be plain-faced, cogged and serrated. The plain-faced wheel puts the grinding in one plane and produces a flat surface; it is normally used when the unit pressure is high enough to cause sufficient break down of the abrasive grains. It usually produces a better surface than the serrated wheel, minimizes shelling, and permits off-hand grinding and polishing of curved and contoured parts. The serrated wheel has lands and grooves angled across the wheel which "sharpen" the grains as they undulate across it.

The contact wheel should be small in diameter and as hard as practicable, thus providing almost line contact and high unit pressure between grains and work. Suitable materials include rubber, plastic or metal. Rubber is usually recommended. Rubber wheels range in hardness from sponge rubber (durometer 10) to rock hard (durometer 100). The harder the wheel, the faster the cutting and the coarser the finish. Softer rubber wheels can be used for blending and for spotting to remove isolated defects.

Titanium sheet is usually ground on a carrier-type machine that holds the work on a table which oscillates under the grinding belt. Machine rigidity is important for holding close dimensional tolerances. Low belt speeds reduce the temperature at the grinding point and thus retard oxidation and welding and reduce scorching or marring by incandescent chips. The optimum speed depends on the contact wheel, grit size, work thickness and grinding pressure.

Feed pressures of 80 to 120 psi. have been used; correct pressure will cause sufficient grain fracture, proper shelling of the belt and an economical cutting rate. Feed should be constant for best dimensional tolerances.

Dry grinding, except for intermittent operations such as blending and spotting, creates a fire hazard. A grinding fluid reduces grinding temperature and quenches sparks.

Table I – Grinding Titanium With Silicon Carbide Belts

Variables	Grinding Operation		
	Spotting	Roughing	Finishing
Grit size	40 to 80	80	120
Speed, fpm.	1000 to 1500	1500★ to 2200	1500★ to 2200
Feed, psi.†	—	120 to 80	120 to 80
Table speed, fpm.	—	10	10
Grinding fluids	No	Yes	Yes

★Preferred. †Feed pressure inversely proportional to speed.

Circle 1709 on Page 48-A

Belt Grinding . . .

High-flash-point grinding oils, applied close to the grinding point, may be used, and water-base fluids containing certain inorganic compounds and rust inhibitors give good results. Soluble oil emulsions in water are poor grinding fluids but can be used where the alternative is dry grinding above 1500 fpm. Liquid CO_2 is the least effective of all coolants tried. Grinding fluid may be applied by spraying or belt immersion.

For paper belts, use heavily sulphurized chlorinated oils (flash point: 325° F. or higher). Cloth belts can use a 10% nitride amine rust inhibitor (in water) or a 5% potassium nitrite solution.

When a potassium nitrite solution is used as a grinding fluid, it must not be permitted to build up around the machine and dry out, as it can become a fire hazard. Exhaust or dust collecting systems should be used to minimize the fire hazard of titanium dust.

W. E. McKibben

Mechanical Properties of Low-Alloy Steels

Digest of "Joint Effect of Sulphur and Rare Earth Metals on the Mechanical Properties of Cast Complex Low-Alloy Electric Furnace Steel", by R. D. Engquist. Paper presented at the A.I.M.E. Electric Furnace Conference, December 1959, Cleveland.

It is common knowledge that excess sulphur in steel has a deleterious effect, causing hot shortness in rolled steels and hot tears in steel castings. It has also been postulated that excess sulphur has an adverse effect on the mechanical properties of steel. However, there is very little documentary evidence to substantiate this. Therefore, the Manufacturing Research Laboratories of the American Steel Foundries initiated an investigation to determine the effect of sulphur on the mechanical properties of a low-alloy, ultra-high-strength cast steel (proprietary name, "Wearpact"). The extent of that effect and the efficiency of methods employed to combat it were also studied.

Eighteen heats of steel were used

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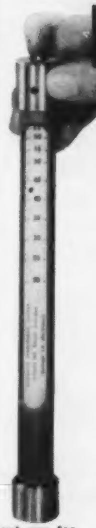

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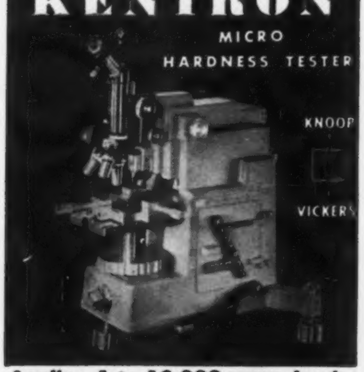

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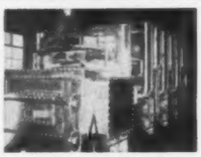

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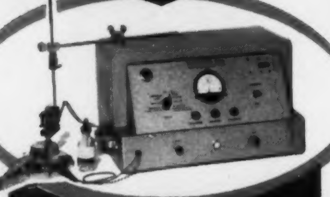

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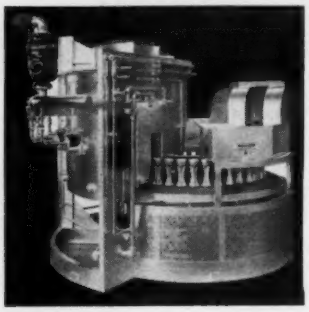

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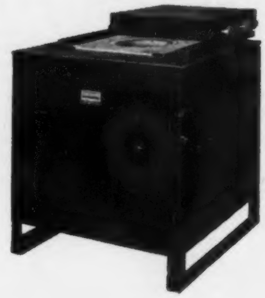

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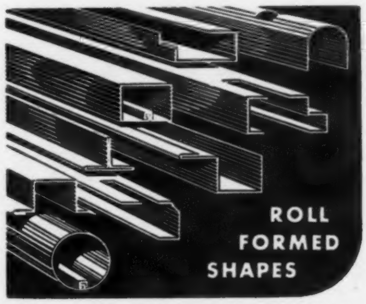

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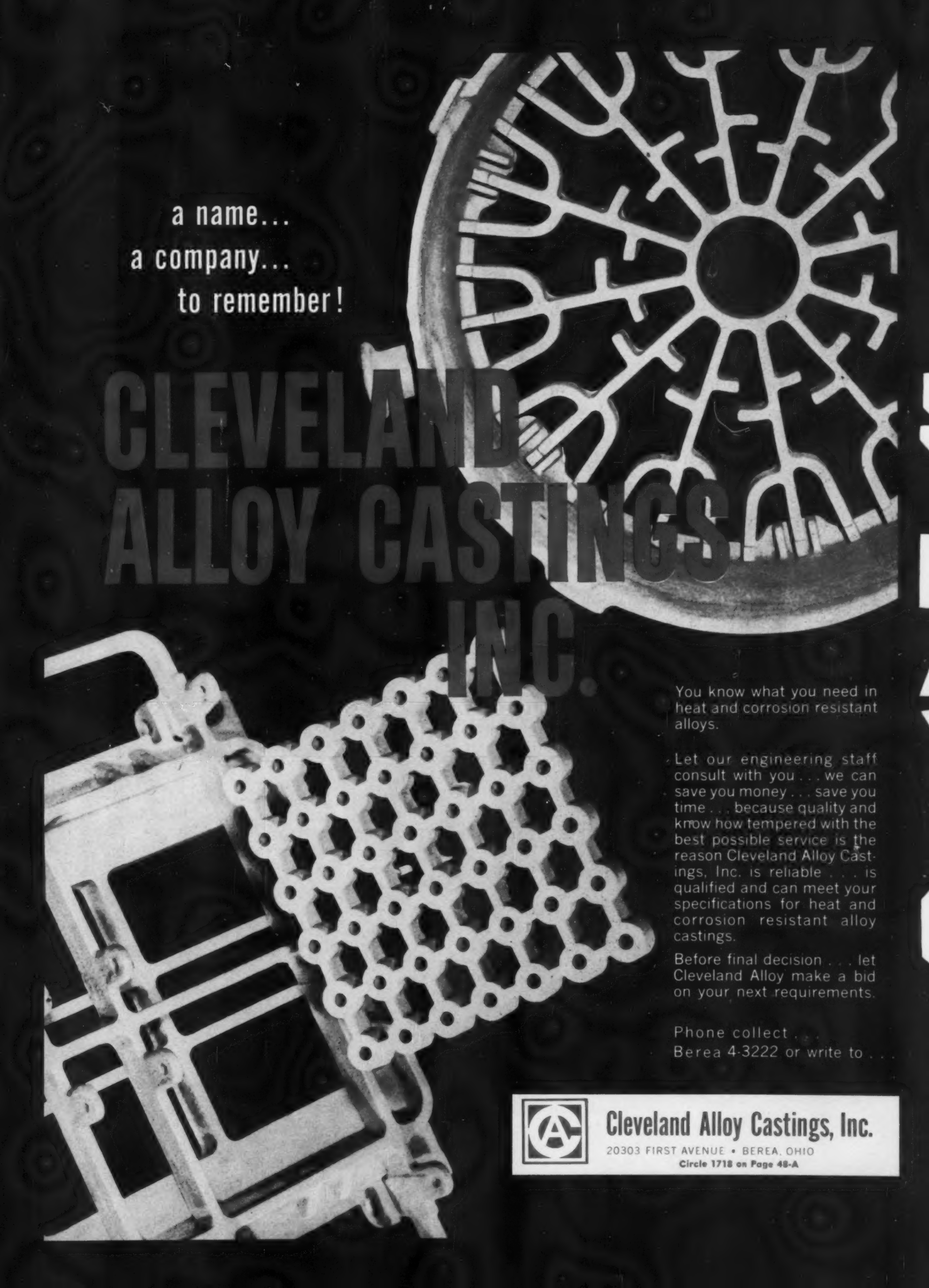

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Circle 1718 on Page 48-A

Low-Alloy Steels . . .

in this investigation, with commercial mischmetal added to nine of them. The compositon of both groups was closely controlled, and the sulphur content was varied from heat to heat. The rare-earth treated groups had sulphur contents ranging from 0.007 to 0.045%. The sulphur contents of the untreated group ranged from 0.005 to 0.045%. All heats were deoxidized with aluminum and a Ca-Mn-Si alloy immediately before tapping.

Double-runner keel blocks were cast from each heat. The runner bars were burned from the blocks and normalized after being held for 2 hr. at 1750° F. They were then used to make tensile test bars and Charpy V-notch impact specimens. After rough machining, all test pieces were austenitized at 1650° F. for 1 hr., and water quenched. Duplicate specimens were taken from each heat and tempered for 2 hr. at each of the following temperatures: 250, 400, 600, 700, 800, 1000 and 1200° F. The specimens were water quenched from the tempering temperature and finish machined. The tensile bars were then aged for 24 hr. at 200° F. All the bars were tested in accordance with standard A.S.T.M. testing procedures.

The test results revealed that sulphur had no effect on the static tensile or yield strength. It did, however, have an adverse effect on ductility and toughness. The results also indicated that the rare earth treatment had a beneficial effect on the ductility and toughness. Its influence appeared to be more pronounced at the higher sulphur levels; that is above 0.015%. This is believed to occur because the rare earth elements promote a rapid scavenging of sulphur from the metal.

The rare earth treatments also seem to be more effective at the higher tempering temperatures. This may be attributed to the effects of temper embrittlement which resulted from tempering at the lower temperatures. The embrittlement reduced the toughness and ductility to the point where it was difficult to discern any improvement resulting from the rare earth treatment.

These tests did not establish the mechanism by which the rare earths accomplished their beneficiation.

Low-Alloy Steels . . .

However, there were indications that an alloying between the rare earth elements and one or more of the metallic elements in the steel might occur. BERNARD TROCK

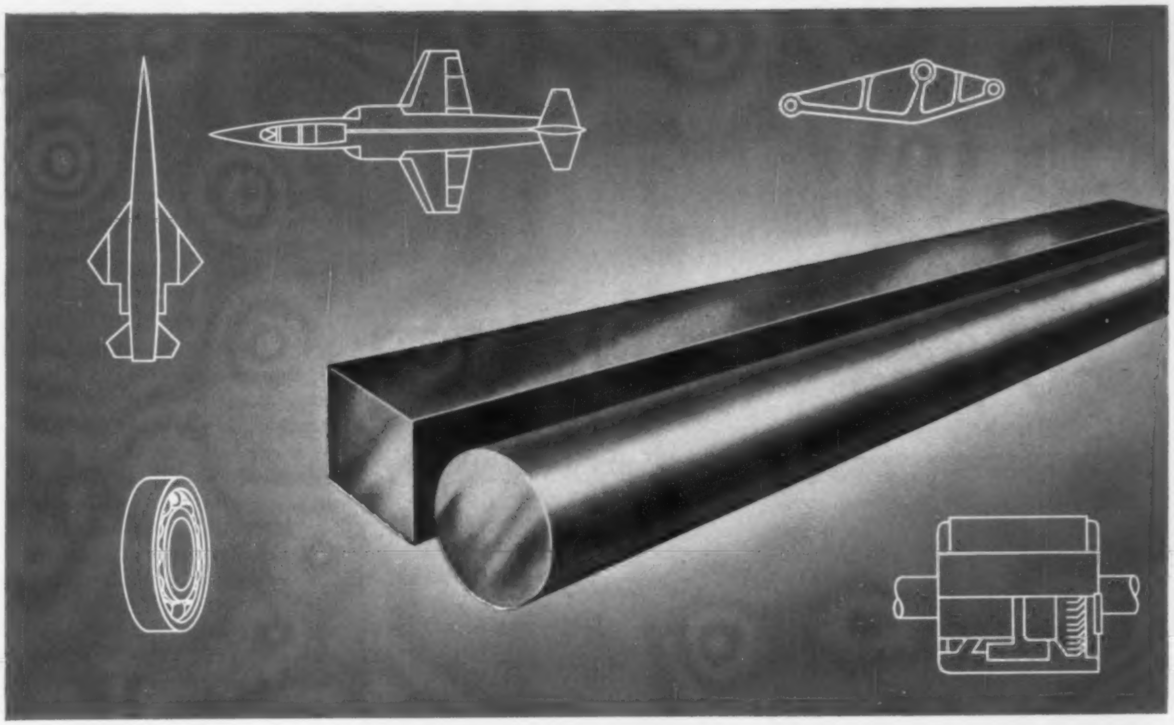
Sliding at High Temperatures

Digest of "Sliding Characteristics of Metals at High Temperatures", by M. B. Peterson, J. J. Florek and R. E. Lee. A.S.L.E. Preprint No. 59LC-5. Paper presented before the A.S.L.E.-A.S.M.E. Lubrication Conference, New York, October 1959.

THE SLIDING CHARACTERISTICS of metals depend upon the strength (hardness), weldability, and film formation. At high temperatures, sliding should therefore be determined by the changes in these factors with temperature. Loss of strength and increased weldability with increasing temperature are detrimental to sliding (as for example copper and magnesium) and to wear rate (as for example aluminum and brass on toolsteel). The properties of the surface film, however, are probably more important. To gain a better understanding of the problem, tests were run with various metals sliding against themselves at temperatures up to 1600° F., and compared with similar tests on alloys containing these metals.

The apparatus consisted essentially of a hemisphere sliding on a flat plate with a reciprocating motion. Load was applied through a friction arm, and the friction force was recorded by a strain gage transducer. The friction arm and test specimens checked the temperature. Before a test, the specimens were thoroughly cleaned and brought to temperature under the test load. Friction readings were then taken. Every 30 min., the temperature was changed as the sliding continued and further readings were made. At the end of the test the specimens were microscopically examined. Standard test conditions were a load of 4.14 lb. and a speed of 0.3 in. per sec.

The pure metals tested (by rubbing against themselves) were iron, copper, cobalt, nickel, chromium, molybdenum and zirconium. Iron,



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Circle 1721 on Page 48-A

Sliding . . .

copper, nickel, molybdenum and chromium pairs behaved similarly, the friction and surface damage being high initially and then diminishing beyond a certain transition temperature. The transition temperature ranges for the respective pairs were 100 to 200° F., 400 to 500° F., 1200 to 1400° F., 800 to 900° F., and 800 to 1100° F. Molybdenum showed a subsequent increase at approximately the sublimation temperature (1460° F.) of MoO_3. Transition temperatures appeared to be associated with the continuous re-formation of an oxide film. With cobalt and zirconium, sufficient oxide was generated at room temperature to be beneficial; friction was initially low and increased with temperature.

To check the effectiveness of the oxides as lubricants, tests were run with a 70% Ni, 15% Cr hemisphere sliding against a plate in the presence of various powdered oxides. In these tests, load was 17 lb., velocity was 0.28 in. per sec., and temperature was 1300° F. Chromium, nickel and iron oxides were brushed from the surface by the sliding action, galling occurred, and the reduction in friction was slight. The remaining oxides of tungsten, copper, zirconium, cobalt, molybdenum and lead formed soft continuous solid films, and gave appreciable reductions in friction. Of these, lead oxide gave the lowest friction; tungsten oxide gave the highest, but no surface damage to the slider or flat was observed. These results illustrate the advantages of soft continuous oxides, but do not explain the behavior of nickel and zirconium whose oxides are harder than the base metals. In such instances, it is suggested that oxide is sliding upon oxide.

A final series of tests was made on certain nickel-base and iron-base alloys – 70% Ni, 15% Cr alloy tool-steel, S.A.E. 1020 steel, 62% Ni, 28% Mo alloy, cast 65% Ni, 28% Cu alloy, and Types 310 and 440 stainless steels. The results were then compared with data previously obtained on the pure metals. The tool steel and S.A.E. 1020 showed marked similarity to the behavior of pure iron. The 70% Ni, 15% Cr alloy showed some similarity to the behavior of pure nickel, the 62% Ni,


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Sliding . . .

28% Mo showed some similarity to pure molybdenum but not to pure nickel, and the cast 65% Ni, 28% Cu alloy showed slight similarity to pure copper, but not to pure nickel.

On the basis of these limited data, it was concluded that there was some correlation between the friction properties of the alloys and those of the major constituents. Also, that a reduction in friction occurred at a temperature sufficient to promote oxidation of the least oxidation resistant component. No values were given for the stainless steels, but it was reported that the Type 310 showed a slight increase in friction at the high temperatures due to thermal softening, whereas the Type 440 showed some reduction.

R. C. A. Thurston

Grain Boundary Structure

Digest of "Structure of Ferrite Boundaries", by V. N. Gridnev, *Metallovedenie i Termich. Obrabotka Metallov*, No. 1, January 1959, p. 19-25.

This paper is an interesting study of the etching characteristics of the grain boundaries of low-carbon iron and low-carbon iron alloys. The author indicates that the observed results can be explained by assuming that the grain boundaries of ferrite are austenite.

Samples of a 0.13% C steel were tempered at 720° C. (1340° F.) for 1 hr., water quenched, sectioned, polished, and etched in 2% nital. At 2200 ×, a second light etching phase was visible at the grain boundaries. On tempering, this phase darkened. Samples of other alloys of iron were quenched and tempered; these also showed dark etching grain-boundary layers. The width of the boundary zones increased with the time of etching. No attempt seems to have been made to identify the grain-boundary phase which one assumes must be the carbide, phosphide, and columbium intermetallic compound. Later discussion and conclusion in this paper would have been aided if photomicrographs had been given of the as-quenched as well as the tempered structures.

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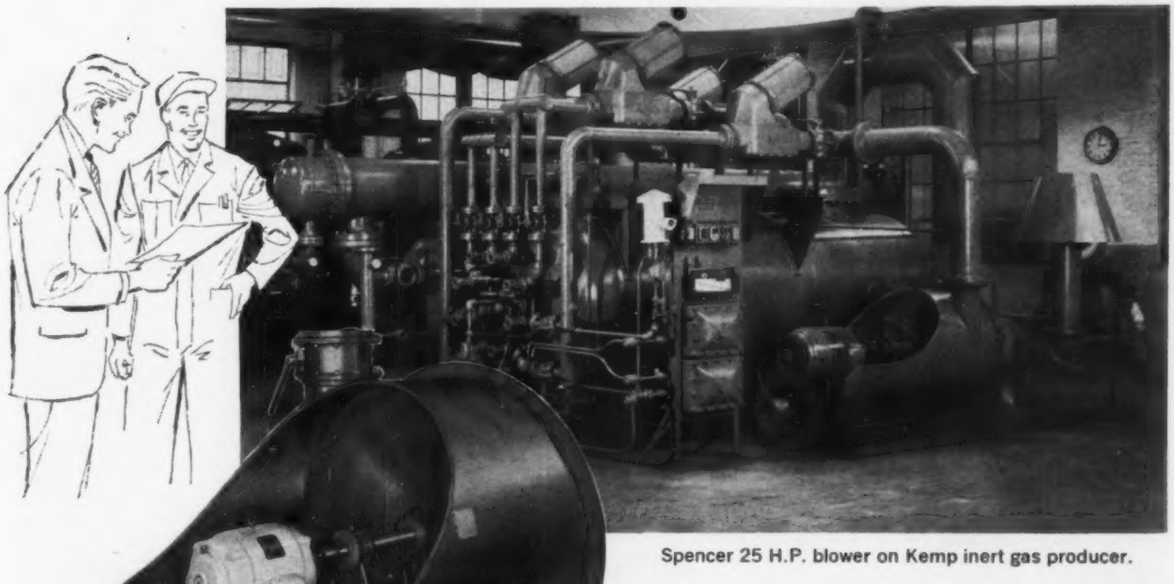

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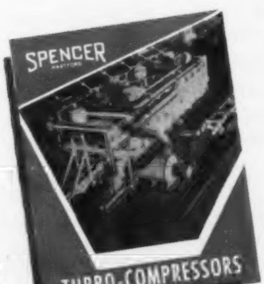

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Circle 1724 on Page 48-A

Grain Boundry . . .

the author states that the boundary layers are:

1. Formed at temperatures at which the rate of diffusion of surface-active impurities is high. In Fe-C alloys these layers form at 550 to 660° C. (1020 to 1110° F.).

2. Formed during both short and long subcritical holding; they are also observed in annealed alloys and welds.

3. Decomposed by holding the quenched alloy at room temperature. Because this decomposition gives a highly dispersed phase, the etched structure becomes darkened. Increase of the tempering temperature, 320 to 350° C. (610 to 660° F.), results in noticeable coalescence of the finely dispersed phase. Heating above 500 to 550° C. (930 to 1020° F.) restores the layers with partial or complete solution of the previously precipitated phase.

According to the author, magnetic, dilatometric and mechanical tests indicate that the layers are austenite. No details or results of these tests are given in the paper. However, reference is made to electron microscopy work at Cambridge which reports the presence of austenite. Electron diffraction results showed that the austenite formed at the boundaries of low-carbon steel contains carbon in the range 0.85 to 1.7%.

On tempering, the austenite first decomposes and then reforms at the higher tempering temperature. The same behavior, however, could be observed if the layers were martensite, which on tempering at 350° C. (660° F.) decomposes. Then, at temperatures in the range 500 to 550° C. (930 to 1020° F.) the precipitate redissolves, to follow the behavior of a secondary hardening steel. Of course, on tempering to a still higher temperature the carbides would be precipitated again.

The author carried out impact tests on two alloy structural steels A and B (no chemical composition given). Steel A was quenched from 930° C. (1705° F.) in water and tempered at 640° C. (1185° F.) for 1 hr., and at 480° C. (895° F.) for 3 hr. Steel B was oil quenched from 920° C. (1690° F.) and then tempered for 3 hr. at 500° C. (930° F.). After tempering, both steels were water quenched. Both the steels were found to be temper brittle. Double tempering induces decomposition of the austenite in the layers with the formation of troosite or martensite (metastable phases). The reversibility of temper brittleness will have to be explained by re-formation of austenite, but in this instance the impact properties of the re-tempered steel should be comparable with the as-quenched alloy (where grain-boundary layers of austenite are present).

The paper is quite interesting and provocative and does take a new approach to the explanation of the grain-boundary phenomena.

W. A. Morgan

(More digests on p. 202)

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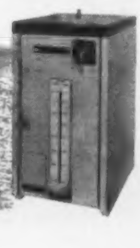

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Thin Foil Studies

Digest of "Observations of Dislocations in Metals by Transmission Electron Microscopy", by J. B. Hirsch, *Journal*, Institute of Metals, Vol. 87, 1958-9, p. 406-418.

TRANSMISSION ELECTRON MICROSCOPY was used first in 1956 to observe dislocations in thin metal foils. Since that time two general lines of research have been followed. Studies have been made of dislocation movement and interaction and of dislocation distribution following deformation, fatigue, quenching or radiation damage.

As for technique, metal foils a few thousand Angstrom thick are transparent in the high-voltage electron microscope. Under these conditions, dislocations are revealed as lines by a Bragg diffraction contrast mechanism. Specimens for these studies have been prepared by two methods: Thin metal films have been evaporated or electroplated or thin foils have been prepared by chemical etching or electropolishing bulk materials.

Dislocations found in these thin foils must be assumed to be representative of those in the bulk metal. In certain deformed polycrystalline face-centered cubic metals, the distribution of dislocations has corresponded exactly with that inferred from X-ray microbeam studies of bulk specimens. Other experimental evidence indicates that the observed distribution of dislocations in thinned specimens is, in fact, fairly representative of that in bulk material.

It is possible, however, that small rearrangements of dislocations do occur on thinning. Isolated dislocations may also reorient themselves into a direction traversing the foil from top to bottom. In these instances, movement is influenced by an interaction with the foil surfaces. Movement in foils is also characteristic and may differ from that in the bulk materials.

Fundamental Dislocation Properties

In micrographs, dislocations appear as lines which are the projection on the plane of the foil of dislocations which run through the foil from top to bottom on an inclined slip plane. When these lines are bowed, dislocations are pinned at

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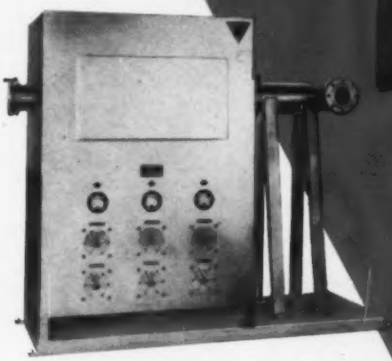

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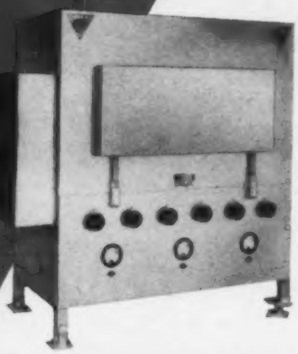

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Thin Foil Studies . . .

the surfaces. Local stresses are often sufficient to cause dislocations to move. All of these movements correspond to glide on the slip planes. When this occurs, a trace appears on the surface which is a projection of the slip plane on the surface of the foil, the contrast being attributed to local strains at the interface between the metal and a surface film. In aluminum these slip traces disappear in about 10 sec., presumably as a result of relaxation, but they persist much longer (if not indefinitely) in stainless steel.

The traces observed in face-centered cubic metals indicate that dislocations glide on (111) planes. Their motion is jerky, the velocity of an individual jump being too fast to be measured. The average rate of movement depends on the frequency of unpinning at the surface. These things all are a result of strong interaction between dislocations and the surface. Thus, the nature of the surface can strongly affect the mechanical properties.

In face-centered cubic crystals, dislocations are expected to be split into partials with a ribbon of stacking fault between them. Suitable stress may drive them apart forming a wide stacking fault.

In the face-centered cubic lattice, screw dislocations dissociate on (111) planes, and lower the energy by forming ribbons of stacking fault bounded by partial dislocations. Screws could also cross slip from one (111) plane to another. This cross slip has been observed frequently in aluminum, copper, silver, gold and nickel, but not on stainless steel or alpha brass. This is consistent with their stacking fault energies.

After a few percent deformation in stainless steel, dislocations appear in a typical network. They pile up on slip planes against a grain boundary, and, by interaction of intersecting slip planes, form hexagonal networks. When interactions cannot glide and are confined to (110) planes, they lead to the formation of networks which are stable when the applied stress is removed.

Theory predicts that as a result of the dissociation of dislocations in the face-centered cubic system alternate nodes of a network should be extended and retracted. Observations have corroborated this. The ribbons of stacking faults usually are not wide enough to be observed directly, but the triangles are considerably wider and can be seen. Size of the triangles depends upon the stacking fault energy.

In pure aluminum, heavily deformed at room temperature, dislocations are arranged mainly in sub-boundaries of various types. The misorientations, as determined from diffraction patterns, are those which would be expected from the nature and size of the dislocation array.

Dislocation loops can be formed by the collapse of disks of vacancies resulting from condensation of these defects in a quenched metal. Two types of loops are to be expected in a face-centered cubic lattice. Dislocations may climb either by absorbing or emitting point defects at jogs. If point defects are absorbed by screw dislocations, helices are formed. Dislocations take up lower energy configurations by climbing. Prismatic loops thus decrease and then vanish by emitting vacancies.

Dislocations in metals of low stacking fault energy are arranged on slip planes either as pile-ups for small deformations or as interaction networks with other slip planes. Also, dislocations are nucleated frequently at the edge of foil specimens. This requires lower stresses than those required in the bulk material.

Distribution of Defects

Dislocation distributions have been studied in several metals. In stainless steel and alpha brass they occur in pile-ups on slip planes. On polycrystalline copper, silver, gold, and nickel, they occur in irregular networks in localized regions rarely with pile-ups. In aluminum, the arrays are similar, but with large deformations they occur on sub-boundaries separating relatively dislocation-free sub-grains.

Differences in dislocation distribution correlate with the difference in stacking fault energy. Correlation in terms of cross slip of screws probably is valid, but the importance of edge climb is not certain.

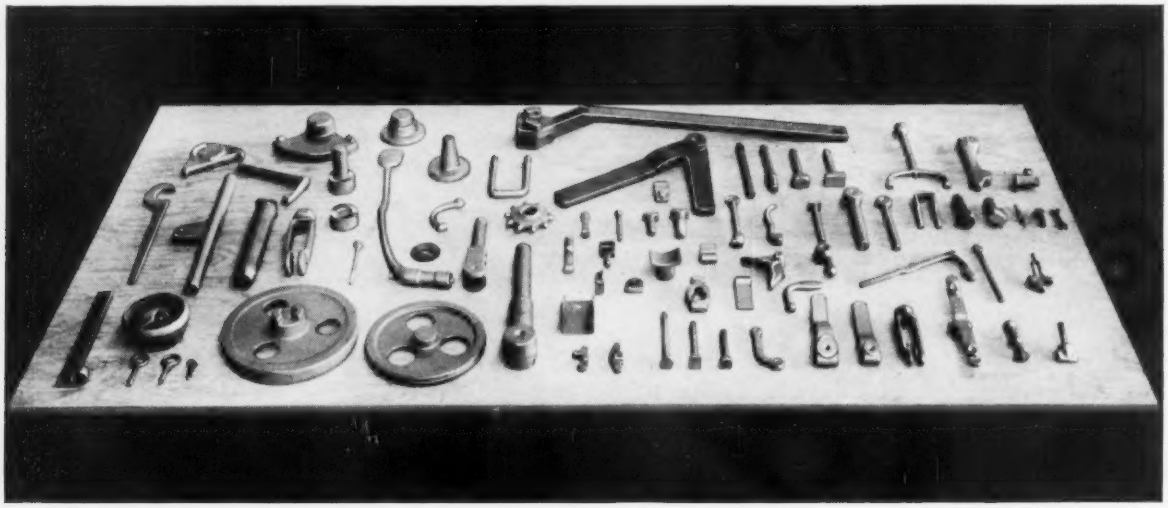
Aside from the face-centered cubic metals, iron seems to have received the most detailed study. After deformation, dislocations occur either

Illustration of Malleable casting being turned at 1,400 surface feet per minute with a 0.100" depth of cut using an oxide tool.

200 Different Parts Heated for Forging-

Better, Faster and at Much Lower Cost

with TOCCO* *Induction Heating*



• When progressive production people at General Railway Signal Company installed a 200 kw, 3000 cycle TOCCO machine, they were able to eliminate 7 slot-type oil-fired furnaces and produce better forging than ever before—at substantially lower costs.

Cost Down—Fuel costs have been reduced from $15.26 to $1.60 per hour with TOCCO. Expensive furnace lining maintenance has been eliminated, and straightening and reheating operations formerly required are no longer necessary.

With oil-fired furnaces all steam hammer operators needed helpers. With TOCCO most of these helper operations have been eliminated.

TOCCO's fast, automatic operation produces almost no scale and achieves uniform temperatures throughout the entire cross section—improving the quality of the forgings and providing increases of up to 400% in the life of the forging dies.

Overall production costs in the forge shop at G.R.S. have been reduced an impressive 35%!

Flexibility—Production runs at G.R.S. range from a low of 15 pieces to a high of over 50,000. Parts from ½ pound to over 25 pounds are heated, merely by changing inductor coils and power control settings.

Better Working Conditions—TOCCO makes the forge shop a better place to work by doing away with noise, dust, dirt, smoke and radiant heat and gases produced by old fashioned furnaces.

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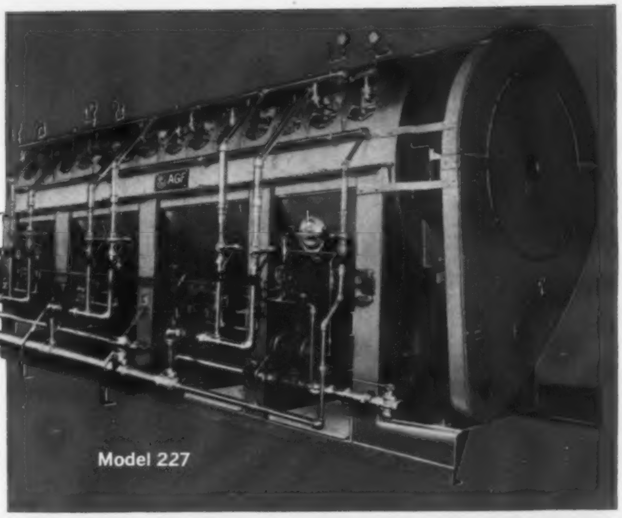
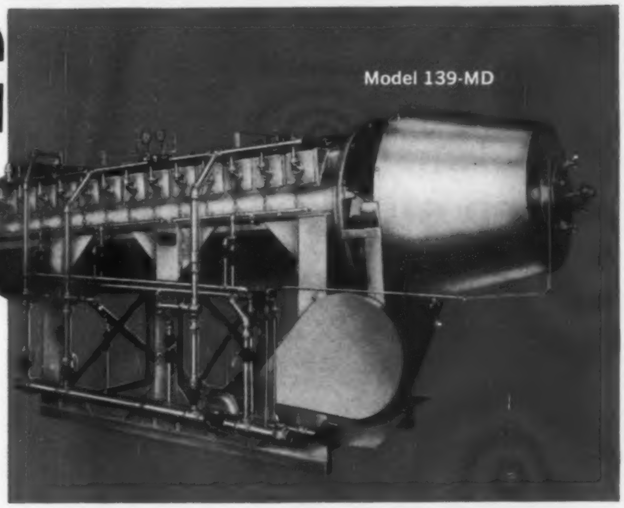
Circle 1730 on Page 48-A

CONTINUOUS CASE-HARDENING or CLEAN HARDENING in the VERSATILE

AGF

Rotary Retort Furnace





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Reduce your heat treating costs with an automatic AGF Continuous Rotary Retort Furnace . . . the furnace with the **BUILT-IN** feeder hopper.

No production requirements are too small or too large . . . **SIZES AVAILABLE FROM 100 LBS. PER HOUR TO 2000 LBS. PER HOUR** . . . These versatile, positive feed furnaces can handle batches of different parts with only a slight interruption in feeding.

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AMERICAN GAS FURNACE CO. 82 YEARS OF PIONEERING 1878 1956 ELIZABETH, N. J.

Pioneers of the first Rotary Retort Furnace in 1902.

AMERICAN GAS FURNACE CO. PIONEERS 1878

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Circle 1731 on Page 48-A

in fairly regular networks or irregular arrangements. There is doubt that they are split into partials on (211) planes. Screw dislocations appear to be able to move parallel to themselves along noncrystallographic paths.

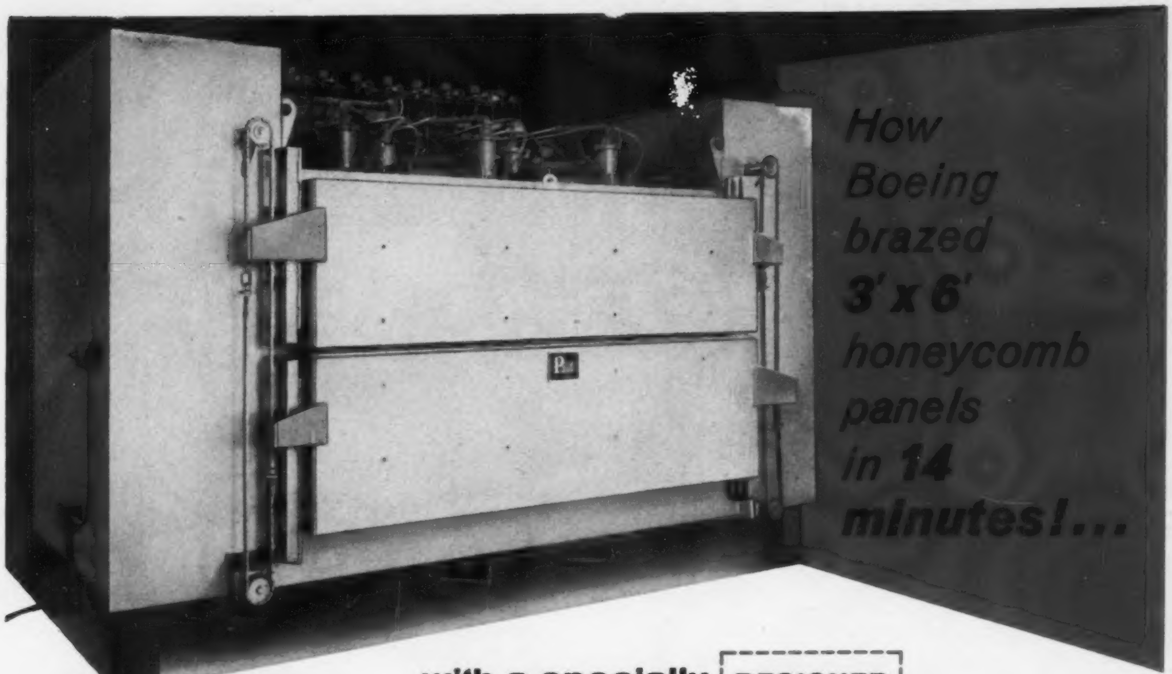
The relation between dislocation distribution inside a bulk metal and plastic deformation is a very important problem. An investigative technique in which the metal, after deformation, is thinned by electropolishing from one side only has been able to reveal simultaneously slip lines and dislocations in the interior. It also shows the magnitude of slip on slip planes by steps at the edges of the thin foil.

After low stress fatigue in aluminum, dislocations are arranged in highly irregular dense networks with little tendency for sub-grain formation. With large stresses, the sub-grain formation is present. As inferred from previous X-ray studies, dislocations in undirectionally deformed or fatigued specimens may differ with low stresses. Results also suggest that large numbers of point defects are created in fatigue.

Drastically quenched aluminum contains many prismatic loops which are formed by condensation of vacant lattice sites into disks which collapse to form these rings. No loops were observed near grain boundaries indicating that such boundaries can act as sinks for vacancies.

There is little doubt that on quenching from high temperature most of the vacancies anneal out by precipitating to form loops or tetrahedra. In quenching from lower temperatures, however, these processes may be more important. Quench hardening is presumably due to the interaction between moving dislocations and these defects.

Prismatic dislocation loops have been observed in quenched aluminum alloys containing solid-solution constituents. The density of the loops decreases with increasing solute content suggesting that most of the vacancies "quenched in" in association with solute atoms. The solubility of vacancies increases in the order of increasing mobility of solute atoms. With decreasing quenching temperature and increasing solute, most of the vacancies



How Boeing brazed 3' x 6' honeycomb panels in 14 minutes!...

with a specially **DESIGNED**

Pacific

RAPID-HEATING PLATEN FURNACE

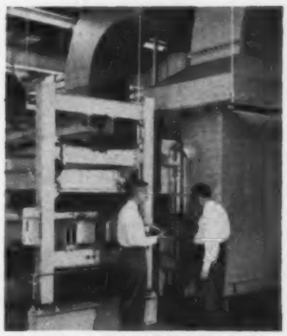
In operation since March 1959, this gas fired Pacific Platen Furnace has provided Boeing Airplane Company with a super-fast method for brazing honeycomb. Teamed with a Boeing press quench, the Pacific furnace has brazed three by six foot steel honeycomb panels within 14 minutes after the start of the heating cycle with thermal gradients as small as ±15°F. at 1675°F.

Charging and discharging operations are swift and simple. The furnace door opens in two sections to save seconds and the honeycomb retort is withdrawn into the press quench positioned directly in front of the furnace. Here the honeycomb is rapidly quenched to room temperature.

The press quench brazing technique eliminates use of graphite reference forms; therefore, much swifter heating can be achieved. Two banks of flat flame burners with eight burners in each bank bring the furnace up to heat in a hurry. Total capacity is 8,000,000 BTU/Hr.

Pacific engineers worked in co-operation with Boeing to produce this excellent solution for fast honeycomb brazing. If you have a similar need or a heat treating problem of any kind, Pacific will be happy to work with you to provide the best furnace to fit your needs.

Call or write now for further information.



Boeing press quench, shown in front of Pacific Furnace, shapes and quenches honeycomb assemblies in one operation, eliminating graphite reference forms.

FURNACE FEATURES INCLUDE:

- Temperatures to 2350°F.
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Circle 1733 on Page 48-A

EVEN ON THIS EXTRA-TOUGH JOB...

N-A-XTRA

HIGH-STRENGTH STEEL TRIPLES TRUCK LIFE!

Hour after hour, around the clock, the Edward C. Levy Slag Company, Detroit, keeps forty 45-ton trucks working under severe conditions. Nearly 30 tons of hot slag are loaded, lifted and dumped on every trip. Each time, the truck body must stand the sudden shock of drop loading, the stress of lifting that load and the grinding abrasive action as it empties.

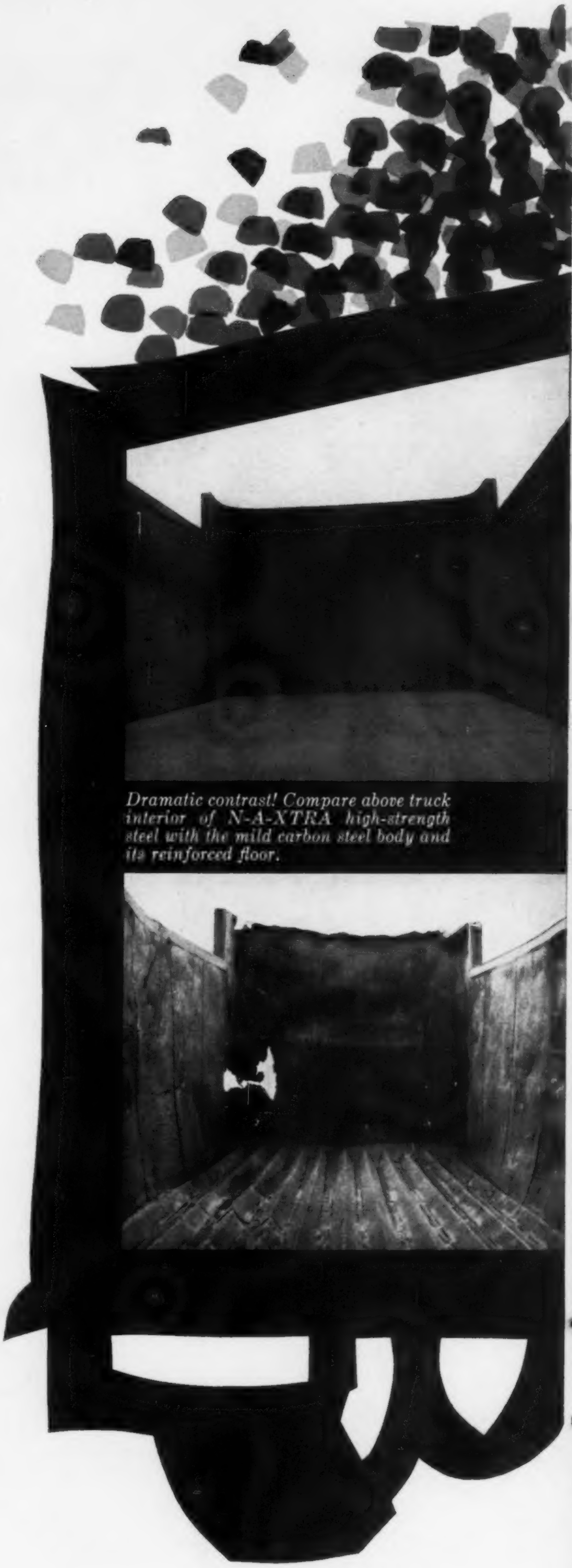
How long can a truck body take such a beating?

Until the company (which designs its own trucks) discovered N-A-XTRA high-strength steel, they used ordinary carbon steel, good for about 18 months' service. Though the truck bodies were as strong as they could be and still carry an adequate payload, maintenance was almost continuous—with breaks, dents, dings and sags occurring almost from the start.

Then they fabricated eight bodies out of N-A-XTRA, which has a minimum yield strength nearly three times greater than mild carbon steel. These trucks carry the same payload and after 18 months' service still look almost new. Owners estimate a life of five years, more than triple the others—with far less maintenance. The extra strength of N-A-XTRA also permits a strong floor that needs no expensive reinforcement to support the load against hydraulic lift action.

Eventually, all forty Edward C. Levy trucks will be made of N-A-XTRA high-strength steel. In fact, all patches and section replacements are now made with N-A-XTRA.

Tons of hot, abrasive slag may not be your problem—but the same steel that mastered these conditions is the one to remember when only the strongest steels will do. Rugged conditions, heavy loads and weight-saving construction are challenges that N-A-XTRA is designed to meet and beat. With excellent weldability, formability and toughness, these quenched and tempered N-A-XTRA steels are available in four levels of minimum yield strength, from 80,000 to 110,000 psi. They can also be supplied to higher levels of mechanical properties.



Dramatic contrast! Compare above truck interior of N-A-XTRA high-strength steel with the mild carbon steel body and its reinforced floor.

N-A-XTRA

A PRODUCT OF

GREAT LAKES STEEL

Detroit 29, Michigan

These two trucks have done the same tough work for 18 months. The only difference is that the one above is made of N-A-XTRA.

Circle 1734 on Page 48-A

Thin Foil Studies . . .

are retained in solution, but some precipitate on screw dislocations changing them to helices.

The annealing of dissolution loops in aluminum recently has been studied with a heating stage in the electron microscope. The temperature at which the loops vanish agrees with that at which the residual resistivity annealed out, thus indicating that residual resistivity is due to loops.

The disorder produced on a metal by neutron or alpha particle radiation has also been studied. Aluminum radiated with neutrons at -196° C. (-125° F.) contained loops and jogged dislocations. Copper radiated with a sufficient neutron dosage at room temperature first showed point defects. With further dosage, a high concentration of larger loops cause the radiation hardening effect.

The transmission electron microscope technique provides a powerful tool for the study of the nature, properties and distribution of dislocations and other defects. It also makes possible studies of the properties of individual dislocations such as glide, climb and interaction and the nature of defects as a function of treatment the specimen received.

R. L. ANDERSON

Bright Anodizing Aluminum

Digest of "Bright Anodizing by the Modified Erftwerk Process", by R. Peek and A. W. Brace, *Electroplating and Metal Finishing*, March 1958, p. 71-76.

THE EXPANDING USE of aluminum for trim items keeps alive interest in bright finishing methods. Chemical brightening provides the best surface for bright anodizing. The article describes a modification of the well-known Erftwerk process used in Europe (British Patent No. 738,711). Operating range is wider, less metal is removed and control requires additions only of ammonium bifluoride and inhibitor.

Better results are obtained by adding an inhibitor to the original formulation to give a bath composition of 13% ammonium bifluoride, 13%

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Bright Anodizing . . .

nitric acid, 1 to 1.5% dextrin. Used at 130 to 140° F., the bath removes 0.001 in. of aluminum per 20 to 30 sec., which usually is enough treatment. Prolonged brightening up to 3-min. immersion produced no adverse effects except greater weight loss. In processing 2650 sq.ft. of aluminum in a 40-gal. tank, ammonium bifluoride was consumed at a rate of 1 lb. per 16.2 sq.ft., dextrin at 0.5 lb. per 10 lb. of ammonium bifluoride. Two gallons of nitric acid were consumed during the entire period. Ammonium aluminum bifluoride precipitates out of the bath as a sludge and is removed periodically.

In the inhibited bath, lead is not as critical as it is in the original Erftwerk bath, and 0.02% improves the specular reflectivity. The ammonium bifluoride contained enough lead to keep the solution at 0.02%.

Like the original, the modified Erftwerk process will brighten superpurity materials only. It is better on 99.8% aluminum, but neither process brightens the commercial alloys well. The impression is that electropolishing and the phosphoric-nitric acid-type chemical brighteners are better on commercial alloys.

Bright anodizing of a chemically brightened pure aluminum surface is best at 10 amp. per sq.ft. in 15% sulphuric acid (3.3 N) at 60° F. At higher current density, specularity of reflection is lowered.

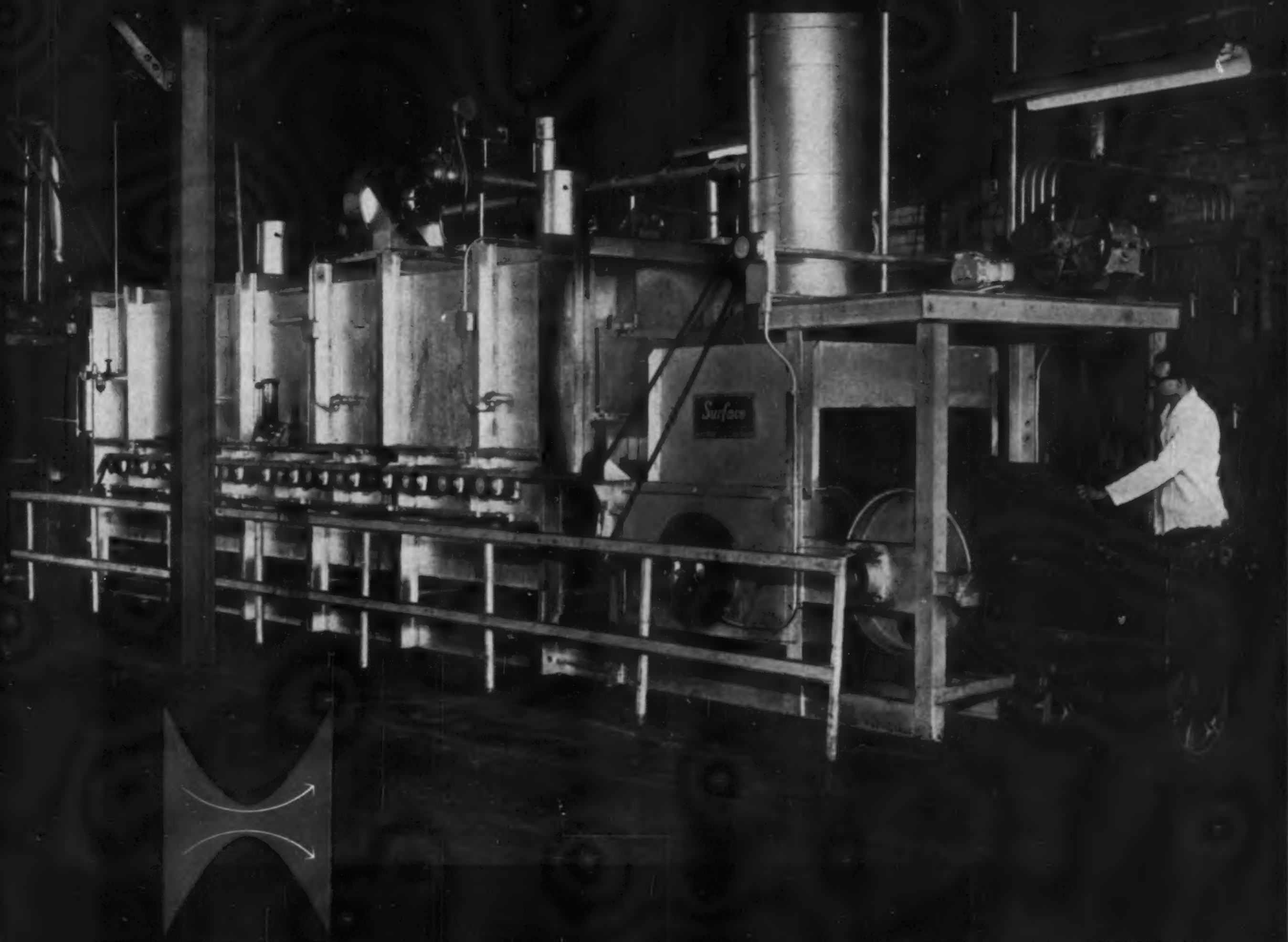
C. L. Faust

Zone Sintering

Digest of "Zone Sintering", by J. Antill and M. Gardner, *Powder Metallurgy*, No. 1/2, 1959, p. 133-142.

This article should be of interest to those involved in the fabrication of powder metallurgy articles. The method described in detail in the paper is applicable to products having one long dimension with respect to the two others, such as rods, tubes, and the like. The basic idea involved in the technique is to sinter the material progressively by moving a rather short furnace surrounding the powder compact from one end to the other. The advantage, and the only one the reviewer can find, is the use of a short furnace of conventional size; this is an economical rather than technical advantage.

The process has been successfully applied to the sintering of metals as well as ceramics, and the authors discuss the sintering of thorium, uranium and an alumina-base ceramic body. The thorium bars, about 1 in. in diameter and 8.5 in. long, were hydrostatically pressed. The platinum-wound sintering furnace had a constant temperature zone of only 2.4 in. and was operated at 1340° C. (2450° F.). Obviously, the rate at which the furnace is moved from one end of the bar to the other has a drastic effect on the degree of sintering, and a critical maximum speed should be expected, above which the degree of sintering is not sufficient to achieve a reasonably high density. For the thorium sintering mentioned above, this critical speed was about 30 in. per hr. leading to a density of about 11.5 grains per cc. The same process has



SURFACE POWER CONVECTION EQUIPMENT

cuts Ross Gear forging process time 50%

High speed, high volume air circulation is the feature of this Surface continuous draw furnace, which enabled Ross Gear and Tool Company, Lafayette, Indiana, to

(1) process a wide variety of steering gear forgings much faster than with the batch type furnaces replaced. These forgings range from a few ounces to 22 pounds.

(2) draw forgings at rates to keep up with production in hardening operations.

(3) reduce handling operations, consequently reassign personnel to more productive jobs.

The furnace has three separately controlled zones, each with its own burners and fan. The uniformity of furnace temperature from zone to zone is consistently held within $\pm 5^\circ$F.

Mr. Leonard Ewalt, Chief Metallurgist of Ross Gear, reports: "The furnace will heat through a 2-inch section in approximately 40 minutes—just about as fast as the metal can take it when heated by convection . . . I would say that with this method of distributing heat in the zones and the rapid heating rate, this Power Convection furnace* is a couple of years ahead of its time.

We're not waiting for tomorrow, either. We're getting results today."

Write for bulletin SC-182. Surface Combustion, 2377 Dorr Street, Toledo 1, Ohio. In Canada: Surface Industrial Furnaces Ltd., Toronto, Ont.

*Trademark of Surface Combustion, Division of Midland-Ross Corp.

Surface A division of Midland-Ross Corporation M-R

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Zone Sintering . . .

been applied to loose thorium powder contained in a beryllia tube. In this instance, however, the compact cracked during sintering. Better results were obtained by presintering the powder in the same furnace at 920° C. (1700° F.) and then resintering it at 1450° C. (2650° F.).

The technique used for sintering uranium powder was very similar to that used for thorium. With uranium, loose powder had to be used because the particular powder involved in the tests could not be cold pressed. The powder was tapped into a beryllia tube 6.5 in. long and 0.4 in. I.D. Sintering was done in two steps, one at 900° C. (1650° F.) and the other at 1100° C. (2000° F.). The final density was about 13.8 grains per cc. for a furnace speed of about 2 in. per hr.

The ceramic body sintered by the zone technique contained 94.35% alumina, 3.25% silica, 1.4% lime and 1.0% magnesia (called Hylumina by K.L.G. Sparking Plugs Ltd.). Normally, this body is fired at 1600° C. (2900° F.) with a firing cycle of 36 hr. Tubes of this material, 1 in. in diameter, 4¾ in. long with a wall thickness of 0.28 in., were presintered by the zone process at 1000° C. (1830° F.) and sintered in air at 1650° C. (3000° F.) with furnace speeds of about 1 in. per hr. In this instance, the furnace was wound with molybdenum for the heating element. This element was protected by hydrogen. Some difficulties were encountered in obtaining straight tubes, and the details of the procedures used to avoid distortion are given in the paper. The authors sum up both the advantages and disadvantages of the zone sintering process.

POL DUWEZ

The 15th METALLOGRAPHIC EXHIBIT

Philadelphia, October 17 to 21, 1960

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everywhere—
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RULES FOR ENTRANTS

Exhibitors do not need to be members of the American Society for Metals.

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable.

Photographic prints should be mounted on stiff cardboard, extending no more than 3 in. beyond edge of print in any direction; maximum dimensions 14 by 18 in. (35 by 45 cm.). Heavy, solid frames are unacceptable.

Entries should carry a label on the *face of the mount* giving:

Classification of entry.

Material, etchant, magnification and other desirable data.

A brief statement (if desired) calling attention to any unusual aspect of the entry.

The name, company affiliation and postal address of the exhibitor should be placed on the *back of the mount* together with a request for return of the exhibit if so desired.

Entrants living outside the United States should send their micros by first-class letter mail endorsed "Photo for Exhibition — No Commercial Value — May Be Opened for Customs Inspection".

Exhibits must be delivered before Oct. 1, 1960, either by prepaid express, registered parcel post or first-class letter mail, addressed:

**Metallographic Exhibit
American Society for Metals
Metals Park
Novelty, Ohio, U. S. A.**

CLASSIFICATION OF MICROS

Class 1. Irons and steels, cast and wrought
Class 2. Stainless steels and heat resisting alloys
Class 3. Aluminum, magnesium, beryllium, titanium and their alloys
Class 4. Copper, nickel, zinc, lead and their alloys
Class 5. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements
Class 6. Metals and alloys not otherwise classified
Class 7. Series showing transitions or changes during processing
Class 8. Welds and other joining methods
Class 9. Surface coatings and surface phenomena
Class 10. Slags, inclusions, refractories, cermets and aggregates
Class 11. Electron micrographs using replicas
Class 12. Electron micrographs (transmission)
Class 13. Color prints in any of the above classes
Class 14. Results by unconventional technique

AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which in the opinion of the judges closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $500 from the Adolph I. Buehler Endowment will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters.

All prize-winning photographs will be retained by the Society for one year and placed in a traveling exhibit to the various ASM Chapters.

42nd NATIONAL METAL CONGRESS & EXPOSITION

Philadelphia Trade & Convention Center——————Oct. 17 to 21, 1960

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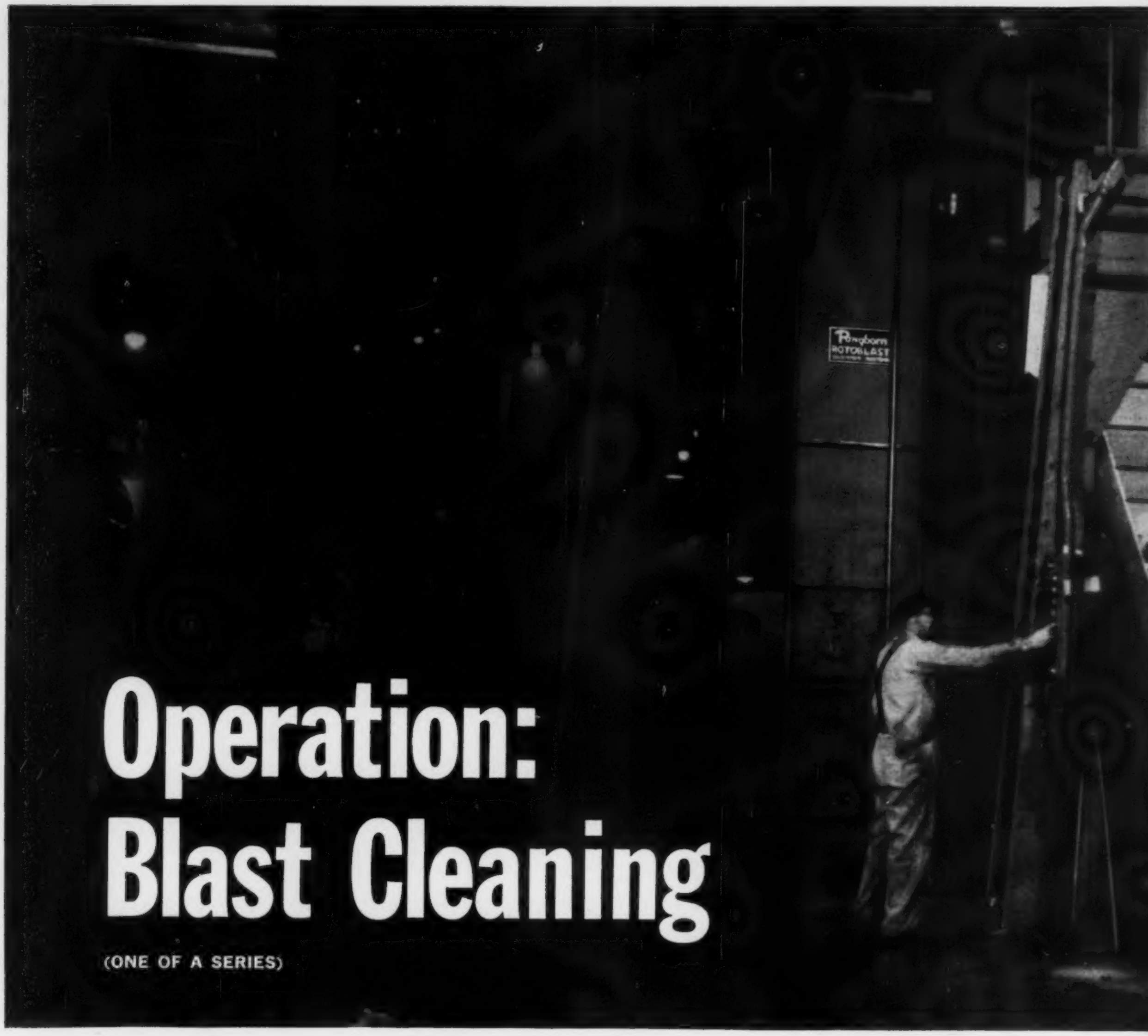
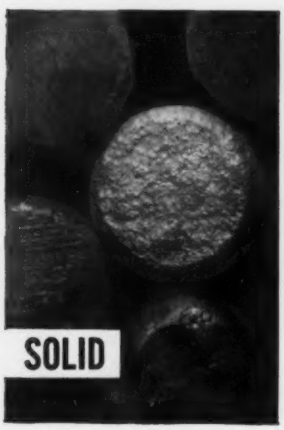


Pangborn Rotoblast proves itself again



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Master Electric Company, Dayton, Ohio—Two 12 cu. ft. Rotoblast Barrels with automation reduce labor costs by 50%—save $15,000 a year in manpower alone! Clean 33 tons of gray iron castings a day with ease.

Meadville Malleable Iron Co., Meadville, Pa.—Pangborn Roto-

And Rotoblast Steel Abrasives

In foundries, forges, steel and metal working plants all over America, premium quality Rotoblast Steel Shot and Grit are replacing other metal abrasives as they *prove* their ability to blast clean at lower cost. Lansing Drop Forge Co.—a typical

Typical Rotoblast Barrel, Ft. Pitt Steel Castings Co., McKeesport, Pa.

...and again...and again...and again!

blast cut 24 man-hours daily to 15 . . . cleans loads three times as large in half the time.

Ingersoll Rand Co., Painted Post, N.Y.—Pangborn Rotoblast cleans 74,000 lbs. of castings per day, cuts cleaning time in half and substantially reduces costs.

Buckeye Iron & Brass Co., Dayton, Ohio—Pangborn Rotoblast is automated to reduce labor requirements even further, cuts 15 minutes blast time to just 4½.

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Pangborn
OF HAGERSTOWN

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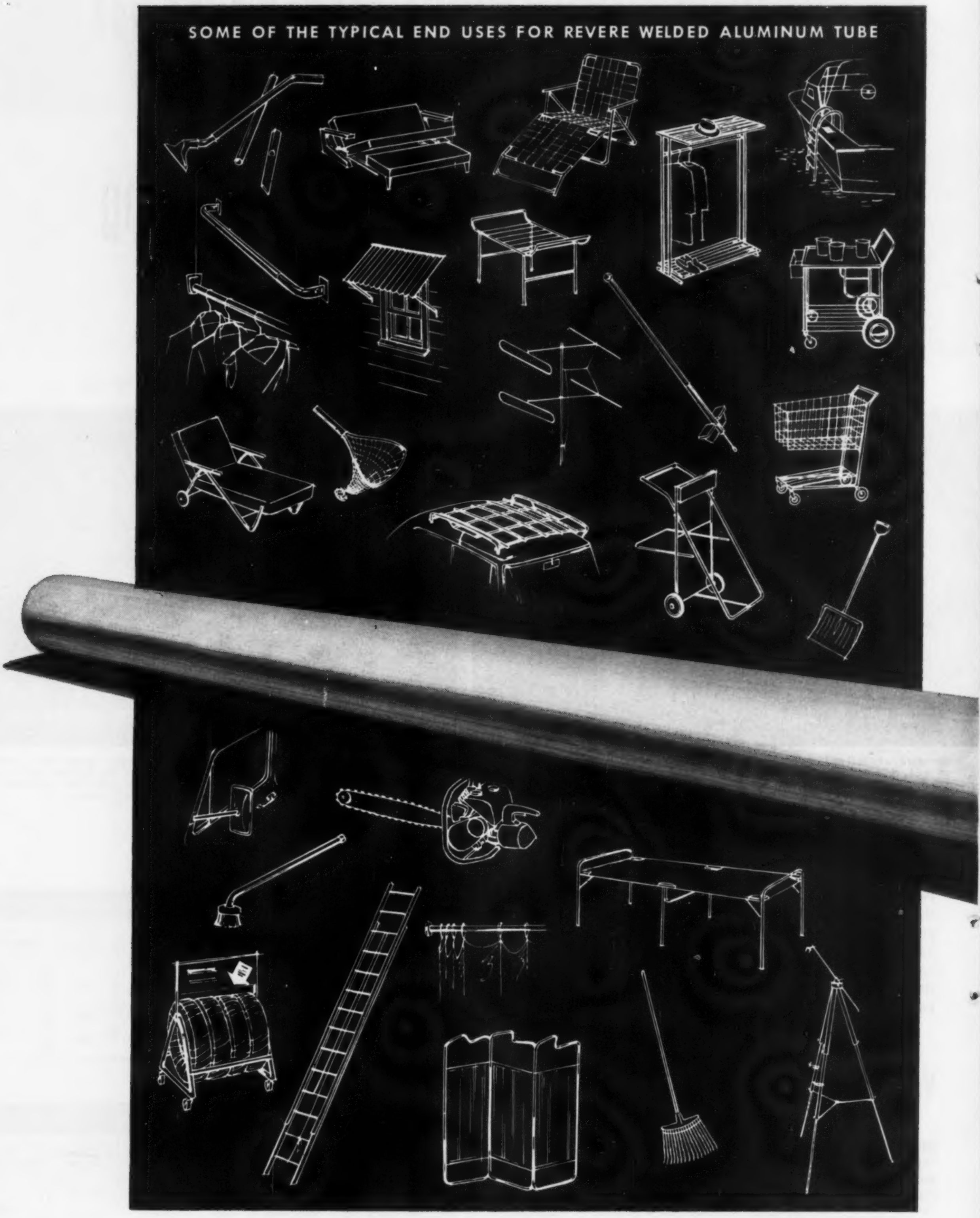
GROWING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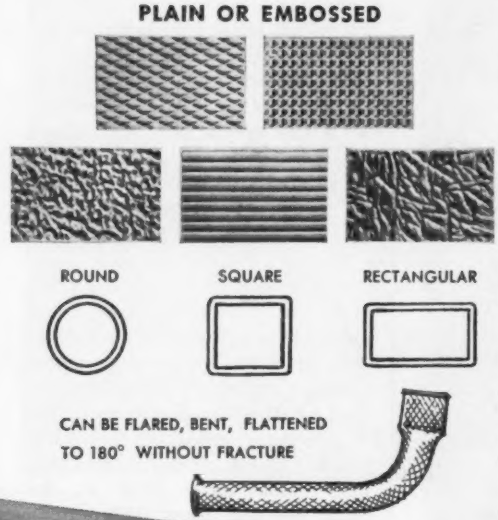

Revere Welded Aluminum Tube is fabricated from rolled sheet by the induction welding process which produces an especially sound joint in aluminum. Because it is of high quality and lower comparable cost than either seamless drawn or extruded tube it can be used to fabricate products for which aluminum tube was never before considered feasible.

As a result, there's hardly a day goes by but that some manufacturer is considering the use of this versatile tube. It comes plain or embossed in a number of patterns, in round, square or rectangular shapes. It can be flared, bent and flattened to 180° (as shown at left) without any sign of fracture. Its formability, strength and excellent finish make it a "natural" for hundreds of applications where light weight, durability, ease of fabrication and eye-appeal are important. Revere Welded Aluminum Tube is available in a broad range of gauges, sizes and tempers within O.D. limits of ½" to 2¼". Lengths up to 30 feet.

Start now to think in terms of Revere Welded Aluminum Tube for your present product or a new one that could be developed by the use of this versatile tube. Send today for sample and further information.

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The OLP Process

Digest of "Comments on the OLP Process", by B. Trentini, P. Vayssière and M. Allard, *Journal*, Iron and Steel Institute, Vol. 192, June 1959, p. 143-147.

THE RAPID ACCEPTANCE of new steelmaking processes requiring the use of pure oxygen has stimulated work on various modifications of such techniques. This article describes the metallurgical aspects of the OLP process, the name assigned by IRSID (Institut de Recherches de la Sidérurgie) to its method of refining hot metal by a stream of oxygen containing lime powder.

The OLP process was studied on a 30-ton basic converter at the Denain steelworks after replacing the standard bottom, which contains tuyeres, with a tight bottom. The oxygen, containing powdered lime, was introduced through a centrally located, water cooled lance inserted from the top of the dolomite-lined vessel. Commercial oxygen, 99.5% pure, was used at a pressure of 90 psi. All of the lime had been crushed to less than 6 mesh and 50% of the powder was less than 65 mesh (Tyler). The fine particle size and the intimate presence of oxygen are said to result in good reactivity regardless of the chemical and physical properties of the lime.

In treating high-phosphorus hot metals by the OLP process, powdered lime is blown from the beginning to the end of the refining period. No lime is intentionally added to the vessel before refining, but some is usually present as a heel from the previous heat. The amount of lime blown into the vessel with the stream of oxygen is adjusted according to the hot metal composition, the stage of refining, and the grade of steel to be produced. No fluxing agents, such as fluorspar, are added with the lime. Ordinarily one or two intermediate slags are removed from the bath by tilting during the refining operation.

In a two-slag process on a basic-bessemer iron containing 1.8% phosphorus and 0.05% sulphur, the first phase consists of blowing about 1800 cu.ft. of oxygen per ton of hot metal. During the first blowing period, the available lime amounts to about 240 lb. per ton of metal. At the end of the first phase, when the temperature reaches about 2900° F., the metal contains about 0.6% carbon and 0.2% phosphorus. Slag is poured off by tilting the vessel. Then scrap or ore is added to adjust the bath temperature, and blowing of oxygen and lime powder is continued until the desired carbon content is reached. For a low-carbon steel, the second blowing period requires about 500 cu.ft. of oxygen and 70 lb. of lime per ton of hot metal. Steels made by such a practice contain less than 0.02% phosphorus, 0.02% sulphur and 0.002% nitrogen.

When working on high-phosphorus metal, the first slag produced by the OLP process weighs about 325 lb. per ton of metal charged. The composition, suitable for fertilizer, is about 52% CaO, 24% P_2O_5, 8% SiO_2, 5% FeO, 4% MnO and 1% MgO. The second slag contains less P_2O_5 and SiO_2, about 30% FeO and 57% CaO. *(Cont. on p. 226)*

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Circle 1796 on Page 48-A

OLP Process . . .

Experience with the commercial-size vessel indicates that the oxygen-lime powder process (OLP) permits consistent control of both bath temperature and slag composition. Both factors influence the final phosphorus and sulphur contents. For a given slag composition, the phosphorus content increases from 0.018 to 0.028% if the temperature rises from 2910 to 3055° F. If the temperature and carbon content at the time of slag-off are known, however, the finishing temperature can be controlled within 35° F. by making appropriate cooling additions of scrap or iron ore. Slag basicity is controlled by altering the additions of lime powder made to the oxygen stream.

Materials balances indicate that 10 to 15% of the sulphur in the charge is lost by direct oxidation during the first stage of blowing in the OLP process. The rest of the sulphur is partitioned between the slag and metal. The partition coefficients range from 2 to 14 and increase with slag basicity.

Temperature does not influence the nitrogen content of steels produced by the OLP process. There is very little pickup of nitrogen during the intermediate tilting operation or during tapping.

F. W. Boulger

Cutting by Electron Beam

Digest of "Electron Beams Machine by Vaporization", *Metalworking Production,* June 5, 1959, p. 986-987.

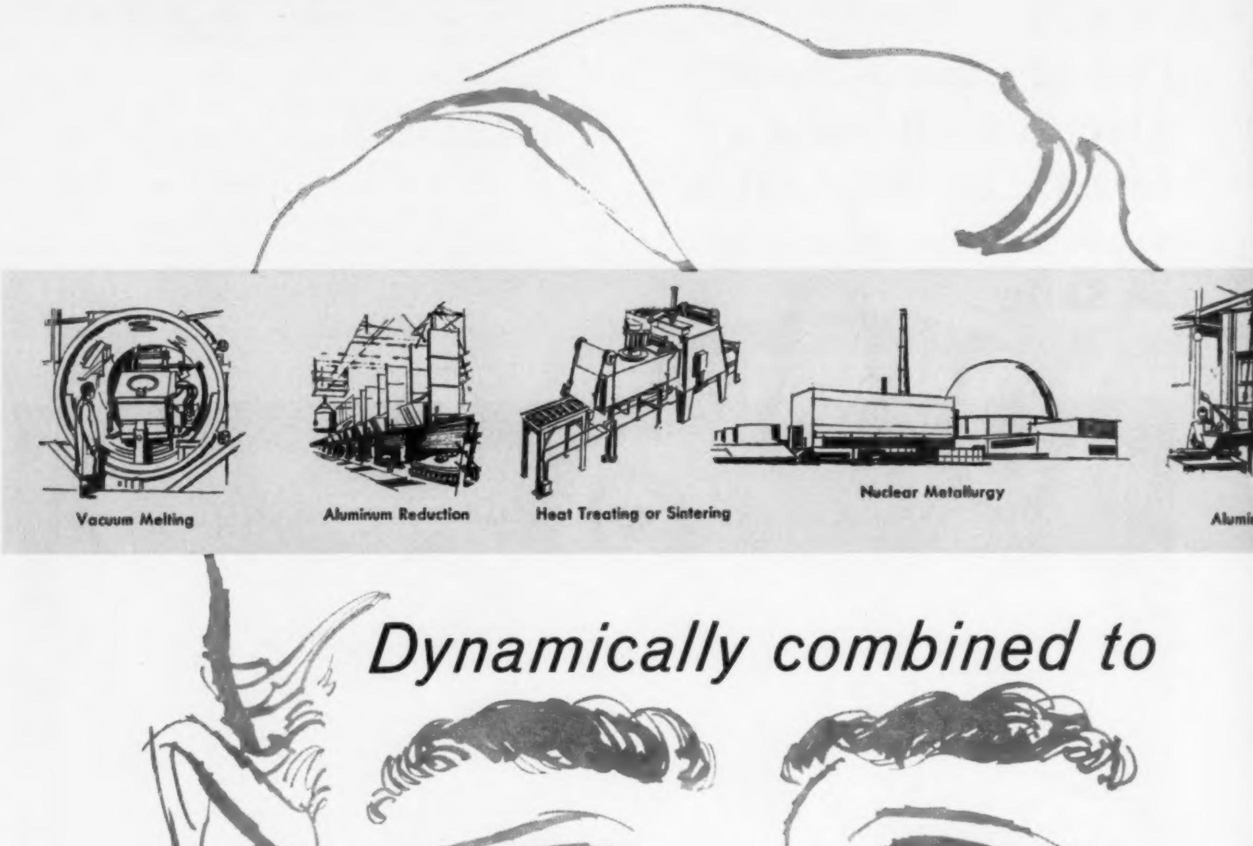
In Germany, electron beams have been used for well over a year to drill and cut holes in tough metals and hard, brittle bearing jewels. For example, even in hard synthetic sapphires, the beam can vaporize holes as small as 0.001 in. diameter. Though the equipment is similar to that for electron beam welding, the beam is focused to a much smaller diameter. In tests, holes but one micron in diameter have been drilled, and the beam is normally half the diameter of the hole it drills. Since such fine focusing is possible, much heat can be concentrated in a small area. Though the equipment can go above 11,000° F. with ease, this temperature has been adequate for any welding, drilling, and cutting.

Width of the heat-affected zone is held to about 10% of the cut by pulsing the beam so that the work can cool between pulses. Any desired frequency between 1 and 3000 cycles per sec. can be attained with pulse durations ranging from 0.01 to 0.00005 sec.

Cut depth has ranged up to ¼ in. with this equipment; cut width is much smaller because the beam must be concentrated. However, this is not significant since it is only necessary to trace the outline of a wide slot to produce the slot. The cutout falls away to leave the desired opening.

It is expected that this equipment will be capable of three-dimensional machining in the near future since cut depth can be precisely controlled.

C.R.W.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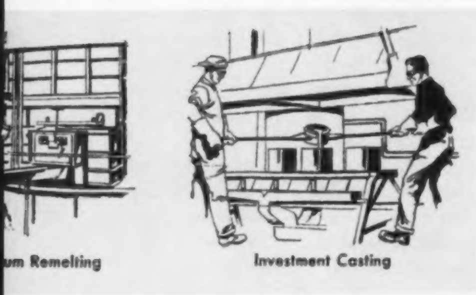

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The Kaldo Process

Digest of "Further Experience With the Kaldo Process", by Bo Kalling and Folke Johansson, *Journal* of the Iron and Steel Institute, August 1959, p. 330-338.

In the Kaldo process, steel is produced by blowing oxygen into a metal bath held in a rotating converter which is tilted about 17° from the horizontal. Characteristically, a larger proportion of the CO formed by the gas-metal reaction is burned to CO_2 in the Kaldo process than in other processes. The additional heat available from this source permits larger amounts of scrap or ore to be added to the vessel. Depending on the composition of the hot metal, scrap or ore additions may be as large as 60 or 14%, respectively, of the weight of pig iron.

The Kaldo process has been used commercially at Domnarvet since 1956, mainly for refining basic bessemer iron (1.8% P). Some work has also been done on low-phosphorus, high-silicon iron. Based on their experience with both steelmaking processes at Domnarvet, the authors believe Kaldo steel is cheaper than basic bessemer steels made with oxygen-enriched air. Plants are being built in Sweden and in France which will use 100-ton vessels. The estimated annual capacity of a plant with two Kaldo furnaces of that size, in alternate operation, is 480,000 tons on basic bessemer iron and 560,000 tons (metric) on low-phosphorus iron.

Kaldo converters are rotated to insure good heat transfer to the bath and to avoid overheating the furnace lining. The slag is kept viscous during the main part of the blow. Then, just before tapping, the iron content of the slag is raised to increase its fluidity. The refining process and the iron content of the slag are controlled by adjusting the direction of the oxygen jet and the speed of rotation. The rate of oxidation and the fluidity of the slag are increased if the oxygen jet impinges on the bath at a greater angle. A higher rotational speed favors formation of a viscous slag with a lower iron content. Decreasing the rotational speed slows down the boil, increases the proportion of CO burned

Circle 1802 on Page 48-A

Kaldo Process . . .

to CO_2 and lowers the temperature of the exhaust gases. Consequently, measurements of exhaust-gas temperatures and currents drawn by the driving motors permit close control of the Kaldo process. This technique results in good control of tapping temperatures and chemical composition. Recarburization is not ordinarily required even for higher-carbon steels.

Rotating the vessel aids in reaching equilibrium between slag and steel. The first slag is low in iron – about 5% when blowing basic bessemer pig iron and less than 2% with high-silicon iron. In refining high-phosphorus irons, two or three slag-offs are common. As much as possible of the final slag is retained in the furnace to be used on the next heat. This conserves lime and iron. The loss of iron in the exhaust gases amounts to about 0.3 to 0.8% of the weight of pig iron. The over-all yield of iron in ingot is about 90 to 93% of the iron in the charge. The yield is better when cooling with scrap than when using ore.

Kaldo furnaces, lined with tar-dolomite bricks, have an average life of 70 heats. The refractory consumption is about 50 lb. per ton of ingots. The relatively short lining life is attributed to the long blowing times required for basic iron and the high temperatures reached by burning the gases to CO_2. The tap-to-tap time for the 26-ton (metric) vessel is about 80 min. of which half is the effective blowing time. Better lining lives (90 heats) have been obtained with burned magnesite brick, and when blowing low-phosphorus hot metal.

Steels made by the Kaldo process from high-phosphorus iron have low metalloid contents. Typical values for rimmed steels are: 0.002 to 0.003% N, 0.010 to 0.030% S, and 0.015 to 0.020% P. Oxygen contents are comparable to those of open-hearth steels with equal carbon contents. Most of the steel has been for ship plate. F. W. BOULGER

Pig Iron in Electric Furnaces

Digest of "Refining Liquid Pig Iron in Electric Furnaces", by R. Durrer and G. Heintze, *Iron and Steel*, May 22, 1959.

AN INTERESTING ARTICLE describing the smelting of 50% hot metal and 50% scrap in electric arc furnaces in Switzerland is reviewed. Heretofore, it had been difficult to charge this large amount of hot metal in electric furnaces because of the lack of oxygen present to oxidize the metalloids in the metal. Large ore additions, necessary when large hot metal charges are used, cause foaming slag and large ejection of carbon monoxide gas. For this reason, large charges of molten hot metal in electric furnaces have never been widely used, even though the high heat content of the hot molten metal greatly reduces the power required to melt a ton of steel.

In this new Swiss operation, the

(Continued on p. 236)

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Circle 1804 on Page 48-A

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METAL SHOW

Electric Pig Iron . . .

hot metal and scrap are charged into the furnace in about 30 min. Power is turned on and the arcs melt vertical, cylindrical, and crater-shaped channels into the scrap projecting above the liquid hot metal. Iron ore (65% Fe) is gradually charged into these cylindrical craters, and a vigorous reaction occurs locally between the metalloids in the hot metal and the oxygen in the ore. By using a high-grade iron ore containing practically no gangue, the amount of slag produced is not greatly increased. Ore can be charged into this gradually widening crater by direct charging so that the ore is mainly contained in the vicinity of the crucibles as they form. The lime required is handled in the same way to insure early slag formation.

After a time, the three separate craters formed by the arcs are finally broken down and the iron ore already charged will largely be dissolved in the slag or reduced to metallic iron. The final molten bath continues to boil uniformly, and the ferrous oxide in the slag is reduced by carbon in the molten pig iron. There are three stages then in making a heat: the charging and intermediate time, meltdown time, and time for finishing the heat.

Described in this investigation are heats containing 50% hot metal and 50% scrap. One grade of hot metal had a phosphorus content of 1.84%; another iron contained 0.085% phosphorus. The high-phosphorus iron metal required more iron ore and more lime to oxidize and slag the phosphorus. A total of 173 heats were made in a 12-ton furnace. Later, 82 heats with low-phosphorus iron and 41 heats with high-phosphorus iron were smelted in a 40-ton furnace. Regardless of the phosphorus content in the hot metal, the phosphorus content of the finished steel was uniformly low, about 0.02 to 0.05%. For the 40-ton furnace heats, the time required for smelting and refining was about 2 hr. on the high-phosphorus and somewhat less on the low-phosphorus hot metal. The kilowatt hours consumed on the 40-ton furnace varied between 328 for the low-phosphorus irons to as high as 350 on the high-phosphorus irons. A 100% cold scrap heat on this 40-ton furnace would ordinarily

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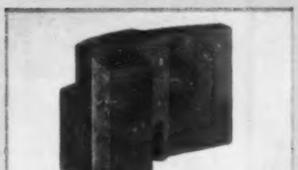

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Circle 1806 on Page 48-A

Electric Pig Iron . . .

consume about 500 kw-hr. per ton of steel melted.

In smelting the high-phosphorus irons, over 200 lb. of burnt lime were required, and a slag weight of about 320 lb. per ton of steel was generated. On these high-phosphorus iron heats, it was therefore necessary to take a slag flush to eliminate most of the phosphorus from the charge. The authors show tables of charge data for all the various heats melted. They also show charts of carbon, phosphorus, manganese and sulphur elimination for both the high-phosphorus iron and the low-phosphorus iron. About 200 lb. per ton of high-grade 65% iron ore were used on the high-phosphorus heats.

The authors have demonstrated in this work that 50% or more of hot metal can be effectively refined in electric arc furnaces by the practices described. Also, the melting rate in tons per hour may be increased from 25.2 (on an all-cold charge) to 33 (on a 50% hot metal, 50% scrap heat). In addition, a saving of about 23% in power consumption is also achieved with the high-phosphorus hot metal.

E. C. Wright

The Metal Rhenium

Digest of "The Availability and Properties of Rhenium", by D. J. Maykuth, DMIC Memorandum 19, Battelle Memorial Institute, May 22, 1959.

Rhenium, a relatively scarce material, is found principally in molybdenite ores, and the Free World reserves are estimated to be about 2,300,000 lb. Rhenium oxide obtained from the molybdenite roasting process is converted to ammonium perrhenate and reduced to metal powder at two places in the United States, the University of Tennessee and the Kennecott Copper Corp. Approximately 100 lb. of metal are produced per year, and current prices for the formed metal range from \$900 to \$2000 per pound.

Pure rhenium compares favorably with tungsten and molybdenum as a high-temperature construction material, although it must be protected against oxidation. Rhenium is not brittle at room temperature in the recrystallized condition. Rhenium generates a large thermal emf. relative to tungsten or molybdenum, is resistant to HCl and H_2SO_4 (even at elevated temperatures), and is attacked by HNO_3.

Rhenium alloys with tungsten and molybdenum (30 to 35 at.% rhenium) are more ductile and have greater hot strentgh at 1200° C. (2200° F.) than tungsten or molybdenum unalloyed. These alloys significantly lower the transition temperature, have higher recrystallization temperatures, and generate very high thermal emf.

Powder metallurgical techniques offer the best production capabilities to prepare wrought forms. Compacts of 90% theoretical density are obtained by pressing at 50,000 to 60,000 psi., vacuum sintering 2 hr. at 1200° C. (2200° F.), followed by self-resistance sintering in hydrogen at 2700 to 2800° C. (4900 to 5100° F.). Desired shapes are produced by step-wise cold working and annealing. The metal can be punched, soldered, and brazed by conventional methods, but machining is very difficult. As a result, coatings have received great attention. The largest single use of rhenium is as unalloyed metal in the tungsten-rhenium thermocouple for temperatures up to 2500° C. (4550° F.). Future uses include improved thermocouple elements, filler metal for welding molybdenum and possibly tungsten, and improved electron tube structural components.

D. L. McElroy

Principles of Heat Treatment

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METALGRAMS

UNION CARBIDE METALS

. . . news about "Electromet" ferroalloys and metals

MAY, 1960

NEW EXOTHERMIC CHROMIUM SAVINGS -- Open-hearth melters using an exothermic ferrochrome ladle practice can save from 50 to 60 cents per ton by using new "Chromtemp" ferrochrome 25-6. The silicon content of the alloy (6.25 lbs. per can) saves the steelmaker money by replacing separate ferrosilicon additions required with straight chromium exothermic alloys. Your Union Carbide Metals representative will be glad to give you further information.

* * *

EXOTHERMIC WITH MORE HEAT -- Closer control of large open-hearth ladle additions can now be obtained with the greater exothermicity of "Chromtemp" exothermic ferrochrome and "Mantemp" exothermic ferromanganese. The improved reaction promotes greater stirring, minimizes segregation, and dissolves the alloy faster. The result is better control of alloy analyses, resulting in fewer off-grade heats. Specification sheets for these alloys may be obtained by requesting F-20,124 and F-20,125.

* * *

LESS GAS THAN EVER -- Producers of vacuum-melted steels and high-temperature alloys have improved their melting operations with new "Elchrome" VG electrolytic chromium. Having less than 0.06 per cent oxygen and extremely low hydrogen and nitrogen contents, this high-purity vacuum-grade chromium has the lowest gas content commercially available. As a result, it's easier to maintain a vacuum and there's less spattering and boiling in the bath. Ask your Union Carbide Metals representative for the analysis of this improved chromium metal.

* * *

EYES ON PHILADELPHIA -- Foundrymen interested in the latest uses of ferroalloys to produce better castings will want to visit Union Carbide Metals' extensive exhibit at the 64th AFS Castings Congress and Exposition, May 9-13, in Philadelphia. The Union Carbide Metals' exhibit covers 41 foundry alloys. Featured are alloys that give better properties to cast iron, allow more efficient production of ductile iron, cut costs of steel, and give greater purity to aluminum. Experienced UCM metallurgists and engineers will be on hand to provide on-the-spot assistance. You are cordially invited to visit the exhibit and talk to UCM personnel. See us at booth No. 1214.

* * *

GASES ARE FLUSHED OUT -- A new alloy -- magnesium-calcium-silicon -- has been used successfully to flush out gases in high-alloy heats melted in the induction furnace. The alloy is added to the ladle and produces a vigorous flushing action. One producer reduced his rejection rate caused by gas imperfections from 30 to 5 per cent on a 35 per cent nickel, 15 per cent chromium casting. For the case history, write for the article, "Rejections Cut With New Alloy," in the Winter 1960 issue of UNION CARBIDE METALS REVIEW or contact your UCM representative for further details.

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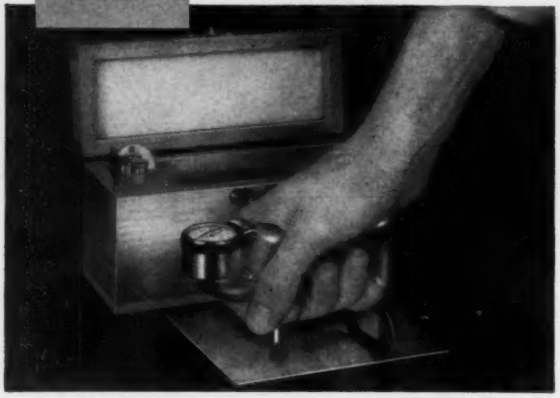

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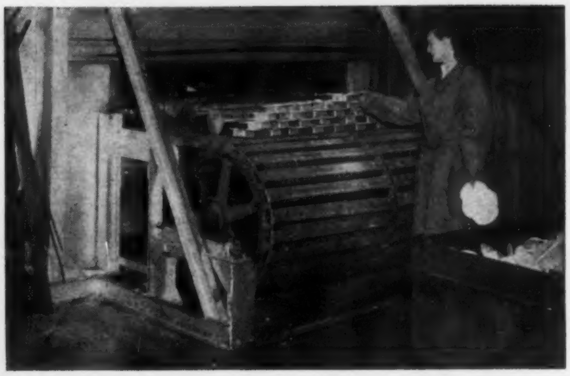

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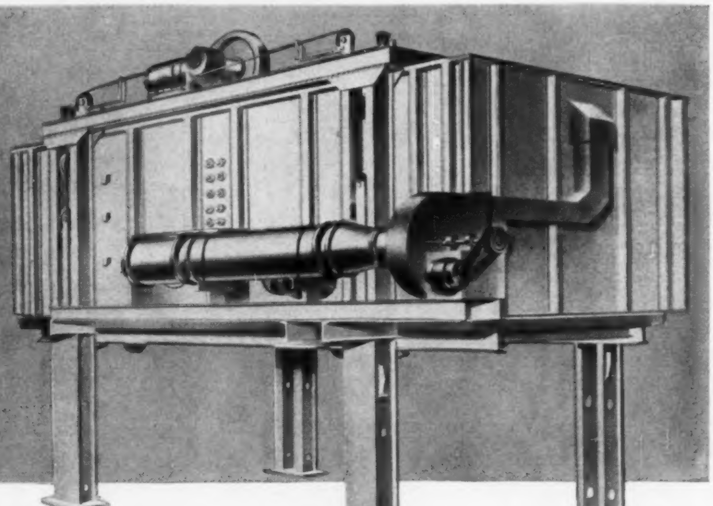

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Circle 1744 on Page 48-A

Question

answer

Who would rock a chair 750,000 times?

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Circle 1808 on Page 48-A

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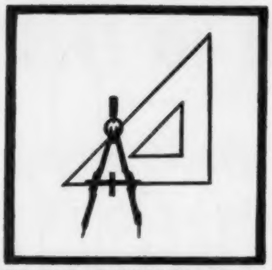

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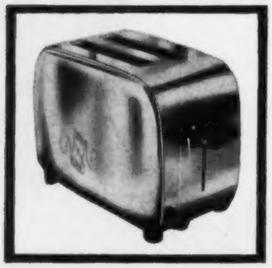

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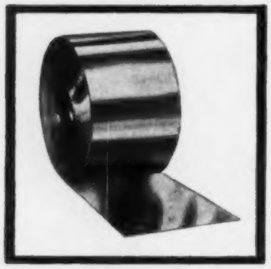

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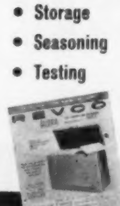

Seven Revco cabinets, both chest and upright styles, are available. Capacities range from 1.5 to 6 cu. ft. in chests and to 22 cu. ft. in uprights. Units provide temperatures to −140° F. controllable within ±1°. Optional accessories are offered. Immediate delivery on all units.

For your FREE copy of the helpful folder, "Selecting a low temperature cabinet," write Revco, Dept. MP-50.

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REVCO INC.
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Setting Trends in Refrigeration Since 1938

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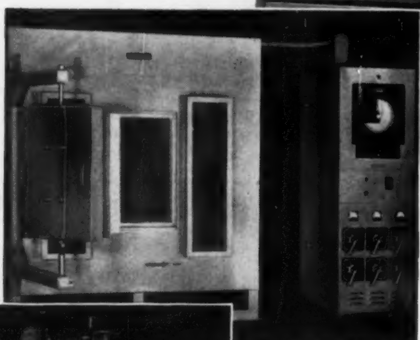
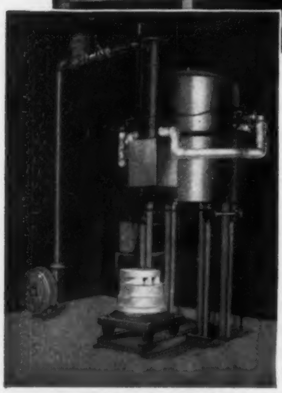
HARROP serves research and manufacturing with standard and special furnaces



Electric — MR Series, Metallic Resistors; radiation or convection heating

Electric — NMR Series, Non-Metallic Resistors; cabinet, box, tube, elevator types



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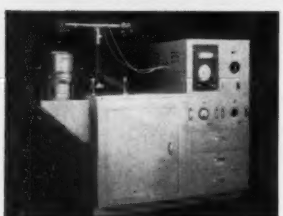
- **Instrumentation** — for any need, both in respect to control and to control forms affecting the time-temperature-atmosphere relations
- **Setting Space** — in diverse form to meet specific need, in shape and size and in mechanical and electrical accessories



Representative of Harrop ability to do the unusual is this interferometer.

For Non-Obligating Recommendations, send information on materials, temperature range, heat control and firing objectives to Dr. Robert A. Schoenlaub, Technical Director.

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Magnesia	MgO	2400°C
Mullite	$3Al_2O_3.2SiO_2$	1800°C
Spinel	$MgO.Al_2O_3$	1900°C
Thoria	ThO_2	2700°C
Zircon	$ZrO_2.SiO_2$	1870°C
Zirconia	ZrO_2	2500°C

For further information write:

LABORATORY EQUIPMENT CORP.
5065 Hilltop Road, St. Joseph, Michigan

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BEHIND THE BYLINES

This month's issue of *Metal Progress* leads off with two articles on the use of clad steels in petroleum equipment – the first, on stresses in high-temperature corrosive environments (p. 71), written by William H. Funk (right) of Lukens Steel Co., author of more than 25 papers on fabrication, special welding techniques and characteristics of carbon, alloy and clad steels. A graduate of Drexel Institute of Technology with a B. S. in civil engineering, he has been with Lukens for 20 years, starting as an engineering draftsman, moving through positions in development engineering, sales development and technical service to his present post of research administrator in charge of all research work for Lukens Steel.

Aside from his daily work activities, philately, Boy Scouts and his community are his primary concern – he is chairman of the Board of Supervisors in the township where he lives and advisor to the newly formed Township Planning Commission.

The authors of "Cladding Steel With Titanium – A Progress Report" – the second article on clad steels – are J. L. Ma and Charles Wright, Jr., shown (in that order) in the photo at left studying an experimental clad steel assembly. Mr. Ma joined Lukens' research division three years ago, following seven years as a development engineer and group leader with Allied Chemical Corp. Now, as supervisor of the clad and process research department, he is responsible for the development of new types of clad steels and new processes for manufacturing and finishing steel products.

Charles Wright has been with Lukens' research division for 11 years, primarily working on the development of clad products using stainless steels, Hasteloy F, aluminum, zirconium and titanium with such methods as roll-bonding, brazing and weld overlay. He has also been responsible for the evaluation of the corrosion resistant materials in laboratory and field corrosion tests.

Mr. Ma is busy in local chapters of A.S.M. and A.C.S. and in YMCA activities, and he also likes to hike, swim and do woodworking. Although studying for a bachelor's degree uses up a good deal of Mr. Wright's spare time, he still manages to serve his community as a volunteer fireman, Sunday School department superintendent and Boy Scout Committeeman. And if he *still* has any time left, tends his tropical fish, indulges in philately, and fishes (for the fresh-water kind).

Eighteen years with Shell Development Co. in Emeryville, Calif., as staff metallurgist gives George A. Nelson (pictured at right) a firm footing for his article dealing with metals used in chemical plants and oil refineries. As staff metallurgist, his work involves assembling of metallurgical information into a form useful to the design, maintenance and inspection engineers in the various chemical and oil plants.

A past chairman of the Golden Gate Chapter, he is a member of A.S.T.M. Committee A-1 and secretary of the Chemical and Petroleum Panel of the joint A.S.T.M.-A.S.M.E. committee on the effect of temperature on properties.

Hobbies include golf, gardening and swimming. He is especially proud of one accomplishment – swimming across Fallen Leaf Lake in the High Sierras (1.1 miles) in 48 min., 52 sec.

The major part of W. L. Steinbrenner's work with Jones & Laughlin Steel Corp. has been in hot extrusion operations (see his article on p. 116). Coming to J&L in 1955 after graduating from Carnegie Tech with a B.S. degree in metallurgy, he worked as a metallurgical investigator assigned to the hot extrusion operation for two years, then joined the process development section of the research and development department as research engineer. He continued his work on hot extrusion until late 1958 when he joined the stainless steel section to work on process problems in the stainless strip area; on February 1 of this year he became development engineer in the stainless and strip division where he will work more closely with mill personnel on process development problems. Mr. Steinbrenner will relocate at the Youngstown, Ohio, plant of the division some time during this coming summer.

Behind the Bylines . . .

Since receiving his degree, he has continued to take graduate work at Carnegie Tech and plans to complete his studies this spring.

A member of A.S.M. and A.I.M.E., he is on the ⊛ Handbook committee on hot extrusion.

⊛ ⊛ ⊛

"Simultaneous Hot Forming and Age Hardening of Titanium Parts" is based on work carried out at Convair's Fort Worth Div. by R. E. Johnson and R. J. McClintick (shown in the photo below examining one of the dies mentioned in their article on p. 130). Bob Johnson joined Convair in 1950 after receiving his B.S. degree in mechanical engineering from the Rice Institute in Houston. His

interest in metal fabrication dates back to his two years work in a metallurgical laboratory in Houston, before starting his college work at Rice. Assigned to the materials and processes group at Convair, he has more or less specialized in the problems involved in choosing and forming the light metals, including titanium, for use on the B-58 Hustler. Dick McClintick was senior metallurgist in the process control department at the time this article was written, but has now left Convair to work on ferrous metallurgy research at Institute Battelle Memorial. Coming to Convair in 1957, his experience included work for Mallory-Sharon Metals and Westinghouse Atomic Power Division.

Bob Johnson's interest centers on sports (basketball, handball and softball) and working in the yard of his new home, helped by his wife and one-year old daughter. Also a family man, Dick McClintick enjoys family group doings with his wife, two daughters and baby son, and plays golf and tennis on weekends.

⊛ ⊛ ⊛

Raymond A. Quadt, author of "Precision Cold Extrusion of Metals", on p. 121, has just completed his tenth year with Bridgeport Brass Co., including tenure with its recently absorbed subsidiary, Hunter Douglas Aluminum Corp. His metallurgical career began with the research department of American Smelting & Re-

fining Co. in 1942; when he left in 1948 he was manager of the general aluminum department. Heading for the West Coast, he joined Hunter Douglas at Riverside, Calif., in 1950 and became vice-president, research and development; in 1958 he moved to New England as vice president, research and development, of the parent company.

For relaxation, he enjoys flying his own plane cross-country on pleasure and business trips, golf and fishing – in that order.

R. F. Harvey is one of the contributors to our 18-page technical forum on modern tool materials (see his article on p. 113, "Working of Metastable Austenite Promises to Improve Toolsteels"). Research metallurgist for Braeburn Alloy Steel Corp., he has developed and holds patents on hot-cold working metastable austenitic steels for improved physical properties and on ultrasonic quenching. A graduate of Worcester Tech, he will be awarded an M.S. degree from the University of Pittsburgh in June.

Another technical forum writer (p. 105), Charles T. Evans is vice-president technology and development for Universal-Cyclops Steel Corp., a company with which he has been connected off and on since graduating from the University of Michigan in 1939 with a B.S. in metallurgical engineering. As shown in the photo, Mr. Evans is a fisherman (he's tying trout and salmon flies in anticipation): the trout on the plaque in the upper righthand corner is a record Brook Trout caught in a river on the Gaspe Peninsula several years ago. His other hobby is golf but he maintains he never lets it interfere with his serious fishing.

Thomas W. Gabriel is well qualified to discuss toolsteel development in our toolsteel forum (see p. 114) for as vice-president, commercial, of Jessop Steel Co., he is responsible for toolsteel sales, research and development and keeps a sharp eye on what his competitors are up to.

He is on the advisory committee of the Zirconium Assoc. and a long-time member of A.I.S.I. and A.S.T.E. As for his hobby – it's golf. Anytime, any place.

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